# Grid Load Relief by Smart Charging of Electric Vehicles

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Energynautics GmbH.

# Agenda

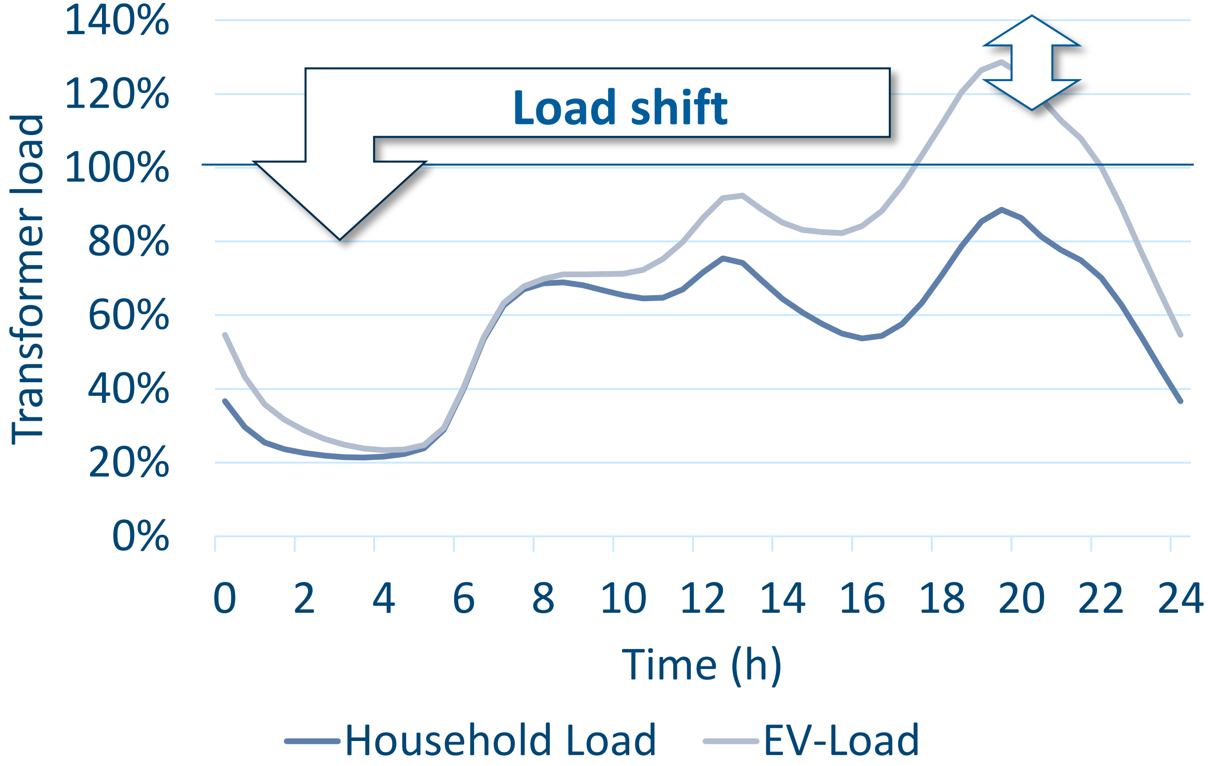
1. Introduction
2. Communication
3. Charging Algorithm
4. Simulation Design
5. Results
6. Conclusion

# 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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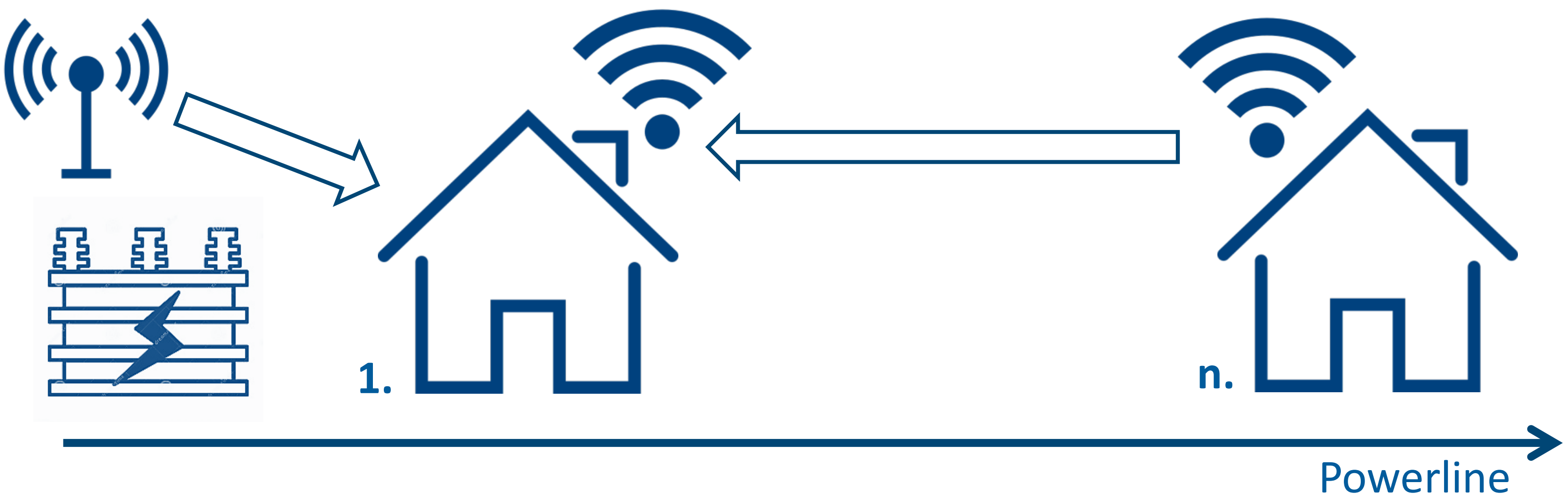
**Communication Effort**

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



# 3. Charging Algorithm

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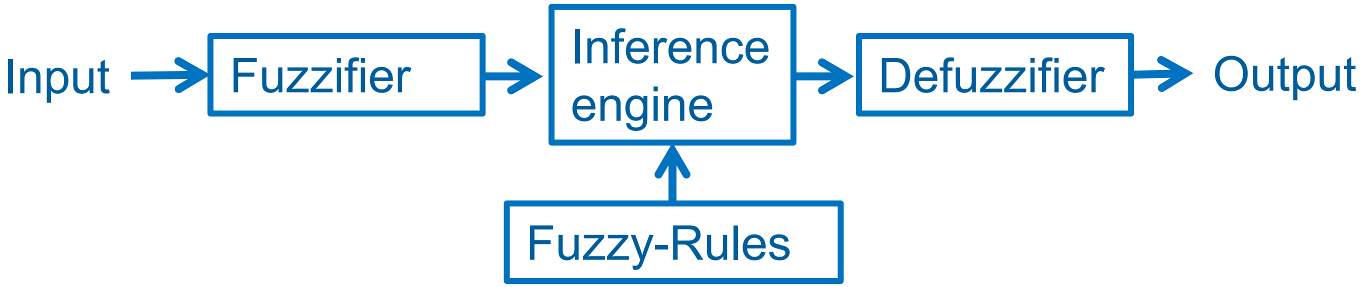
**Fuzzy Control:**

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




**Reactive Power Control:**

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

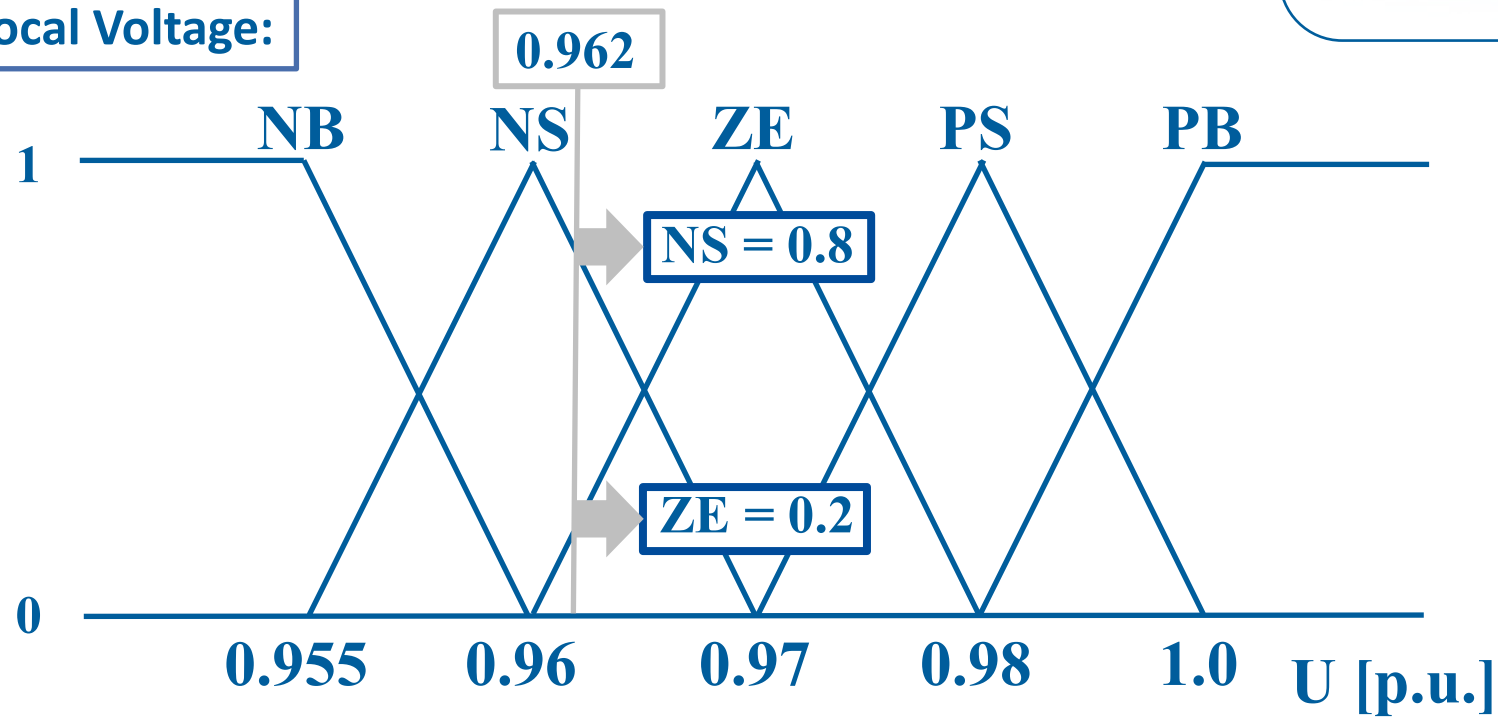
# 3. Charging Algorithm

**Fuzzy Control Fuzzifier**

- Input Data into Fuzzy-areas
- "Negative Big" to "Positive Big"

Voltage:
NS = 0.8
ZE = 0.2

**Local Voltage:**



# 3. Charging Algorithm

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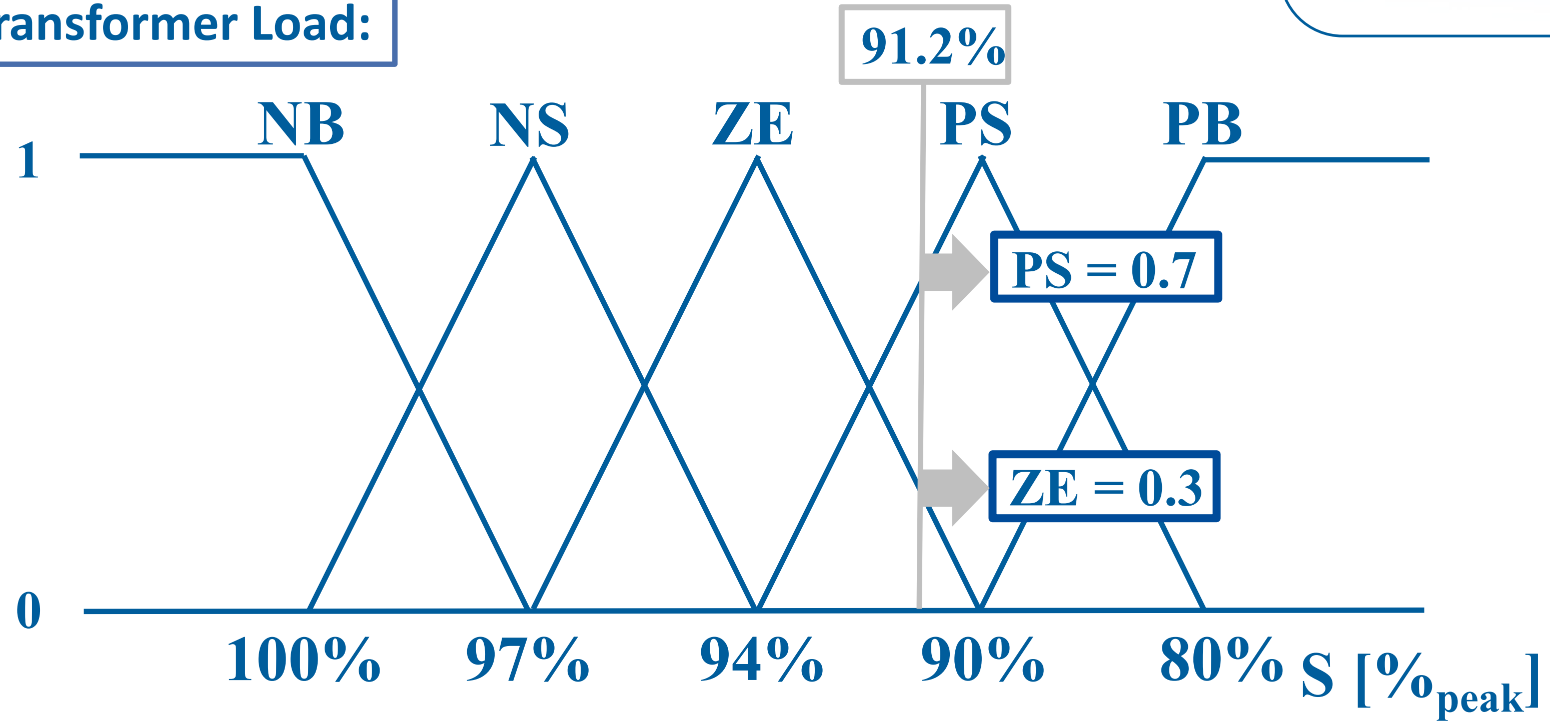
**Fuzzy Control Fuzzfier**

- 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

**Inference Engine:**

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

**Fuzzy Rules:**

| Voltage | TB $NB_T$ | $NS_T$ | $ZE_T$ | $PS_T$ | $PB_T$ |
|---|---|---|---|---|---|
| $PB_V$ | $ZE_L$ | $PS_L$ | $PB_L$ | $PB_L$ | $PB_L$ |
| $PS_V$ | $NS_L$ | $ZE_L$ | $PS_L$ | $PB_L$ | $PB_L$ |
| $ZE_V$ | $NB_L$ | $NS_L$ | $PS_L$ | $PB_L$ | $PB_L$ |
| $NS_V$ | $NB_L$ | $NS_L$ | $PS_L$ | $PB_L$ | $PB_L$ |
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Voltage:
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$$\mu_{min,PB_L} = \min(0.8\ ;0.7)$$

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

# 3. Charging Algorithm

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# 3. Charging Algorithm

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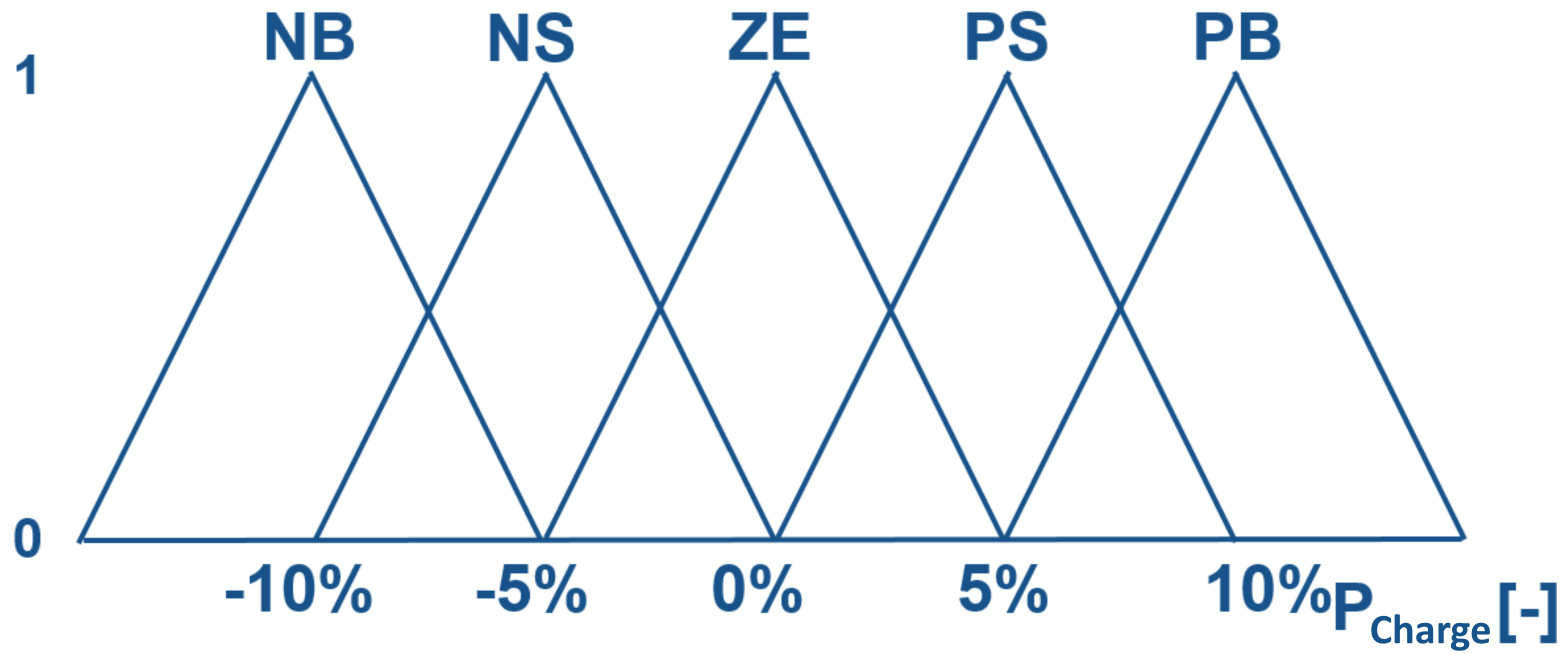
## Defuzzfier

**Charging Power:**




$\mu_{min,PB_L} = 0.2$

$\mu_{min,PS_L} = 0.2$

# 3. Charging Algorithm

$\mu_{min,PB_L} = 0.7$
$\mu_{min,PS_L} = 0.3$
$\mu_{min,PB_L} = 0.2$
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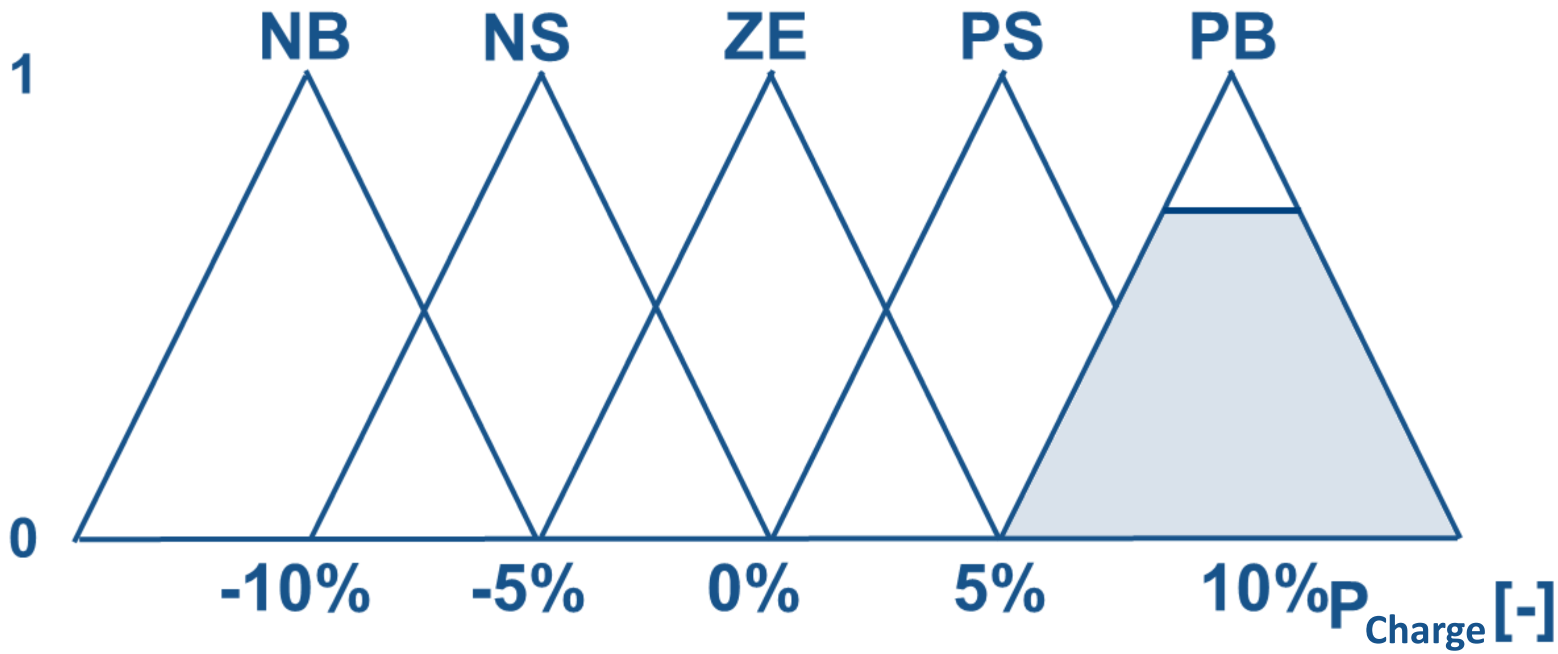
**Defuzzfier**

**Charging Power:**



# 3. Charging Algorithm

### Defuzzfier

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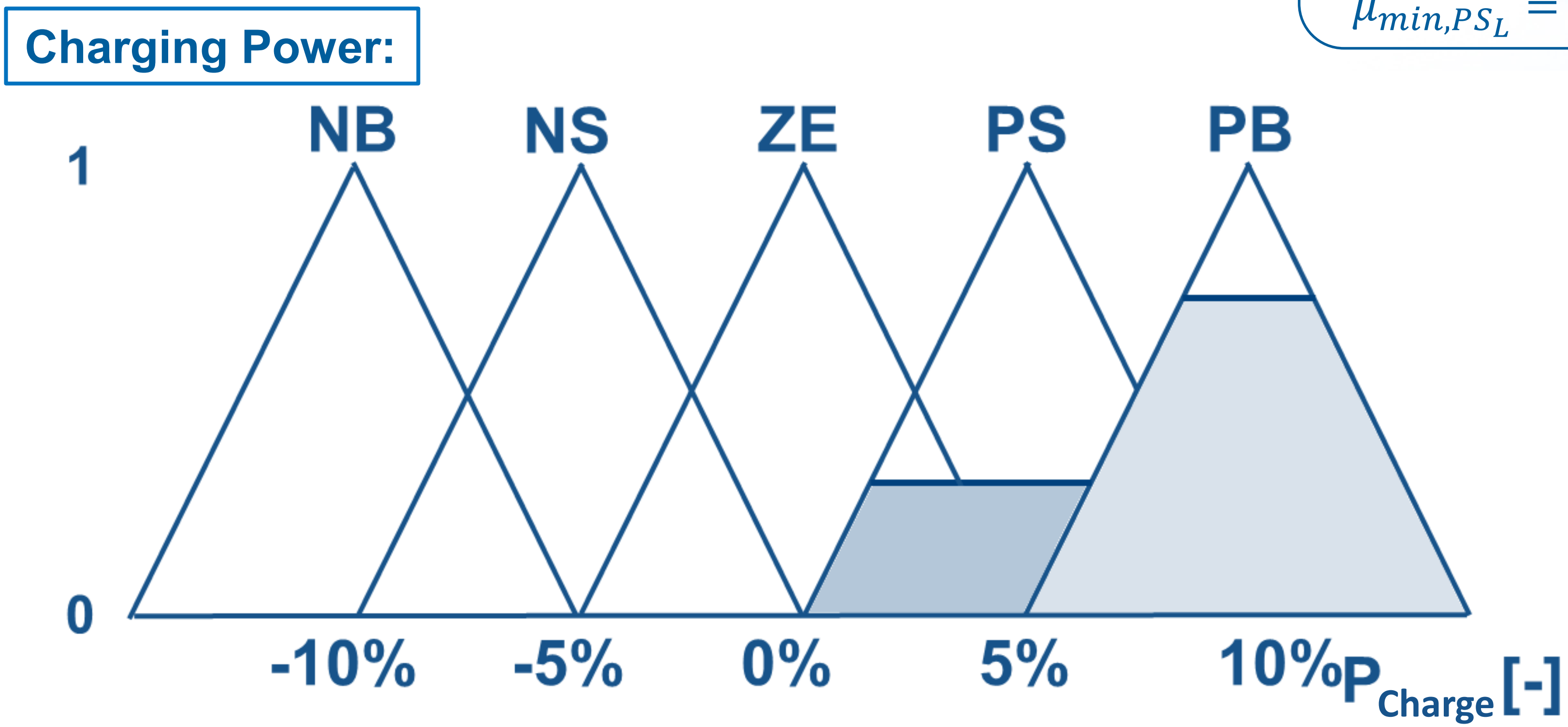

# 3. Charging Algorithm

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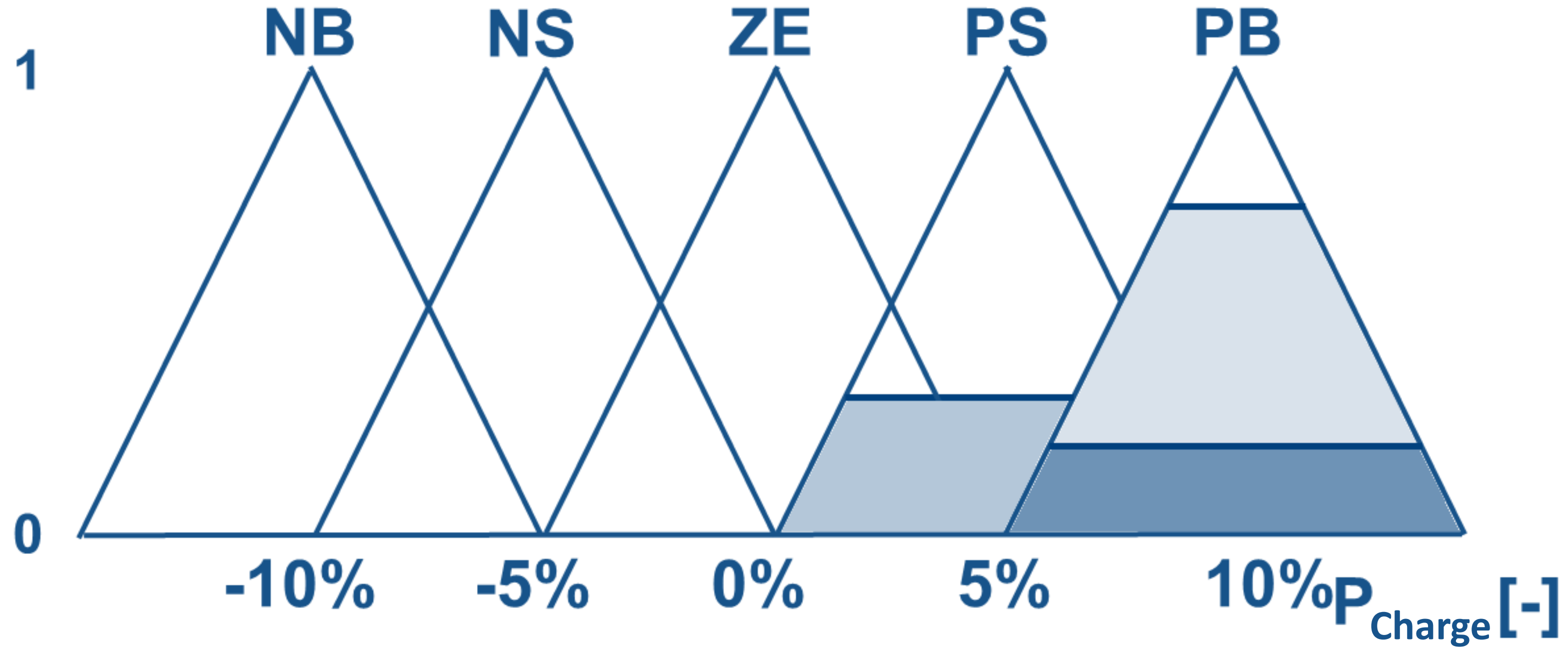

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$$\mu_{min,PB_L} = 0.7$$
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**Defuzzfier**

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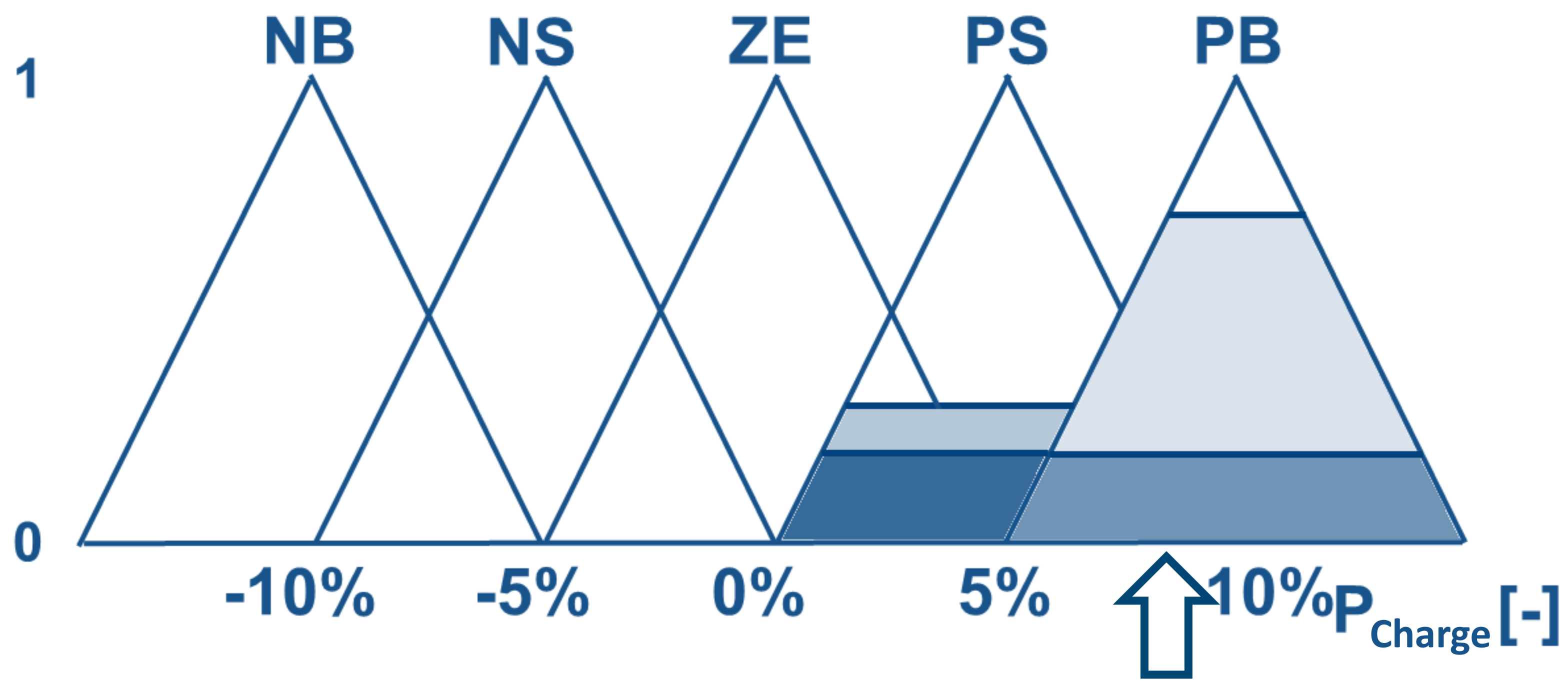
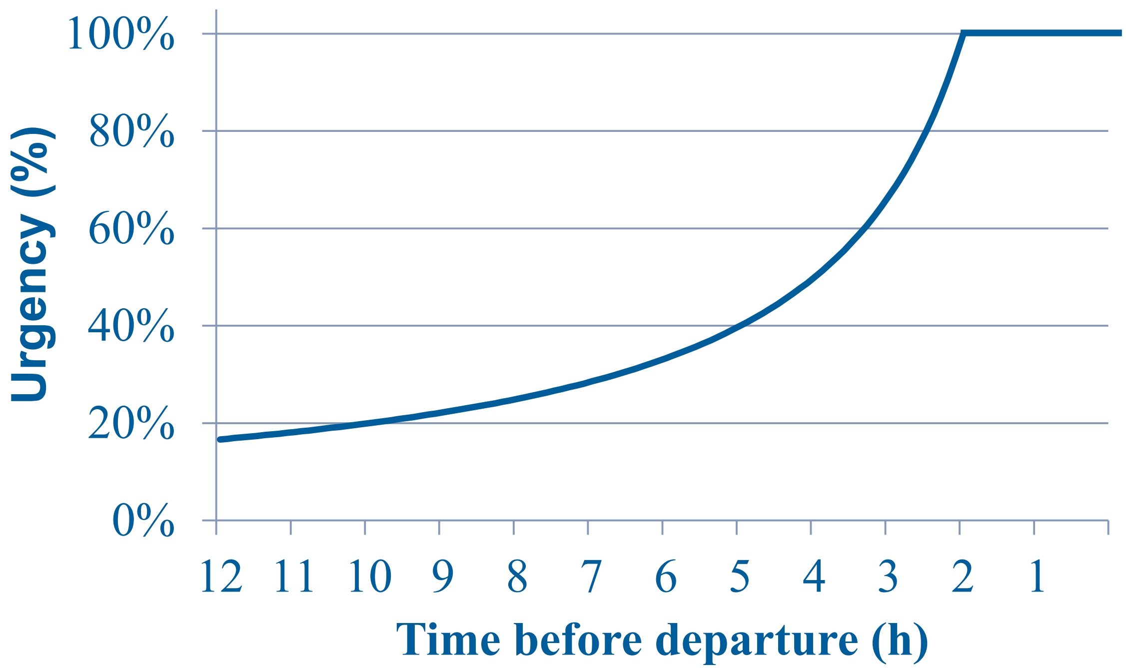



$$\Delta P = 8,2\%$$

# 3. Charging Algorithm

## Urgency-factor

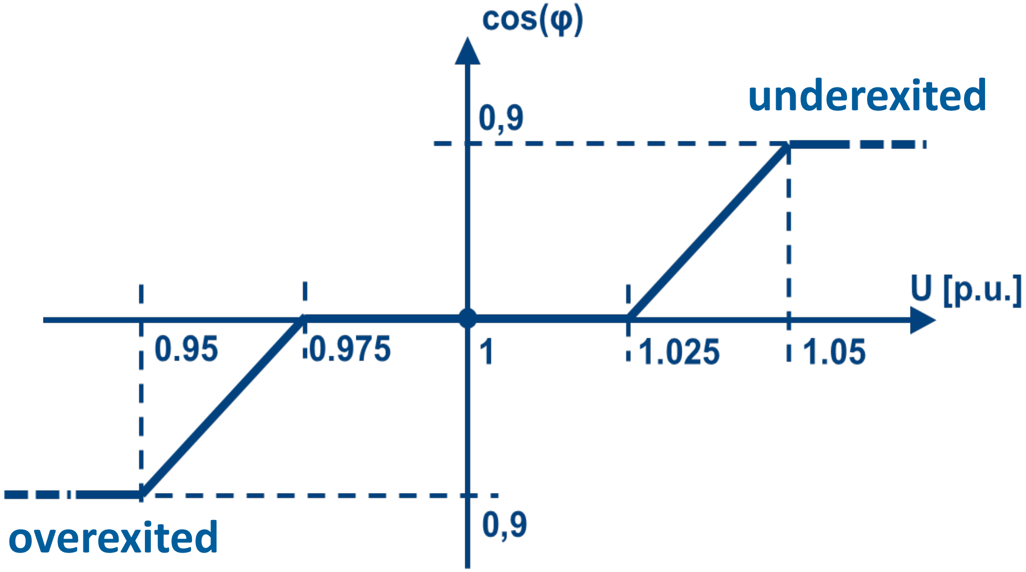
$$Urgency = \frac{Min.\, charging\ time}{Time\ until\ departure}$$



# 3. Charging Algorithm

**Reactive power control**

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



# 4. Simulation Design

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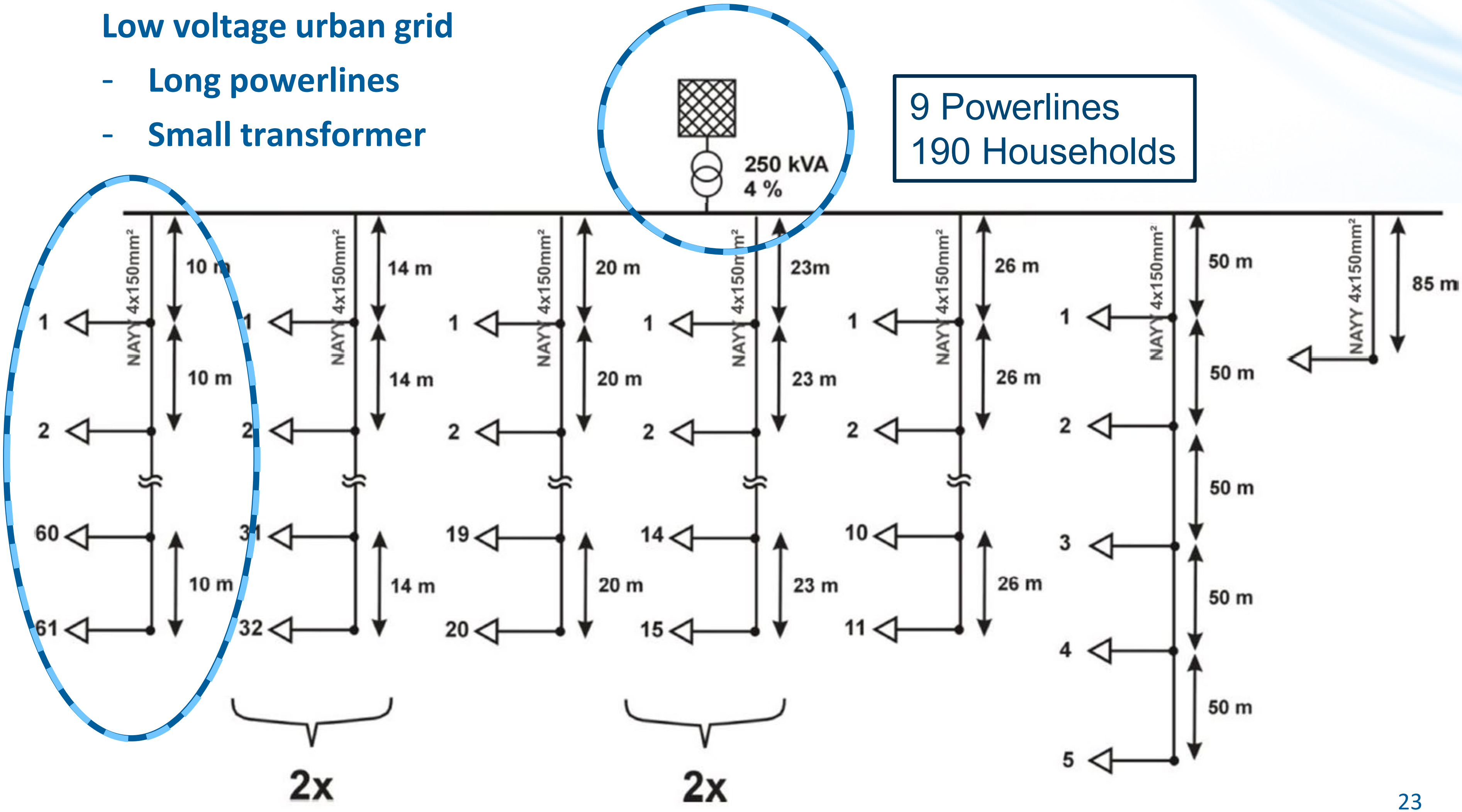
Low voltage urban grid
- Long powerlines
- Small transformer

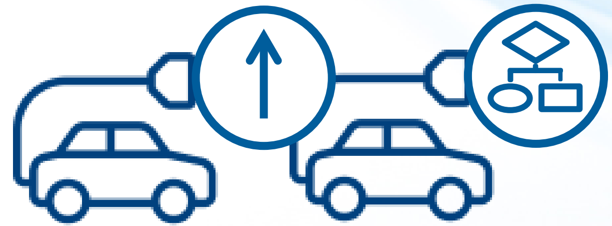
9 Powerlines
190 Households



# 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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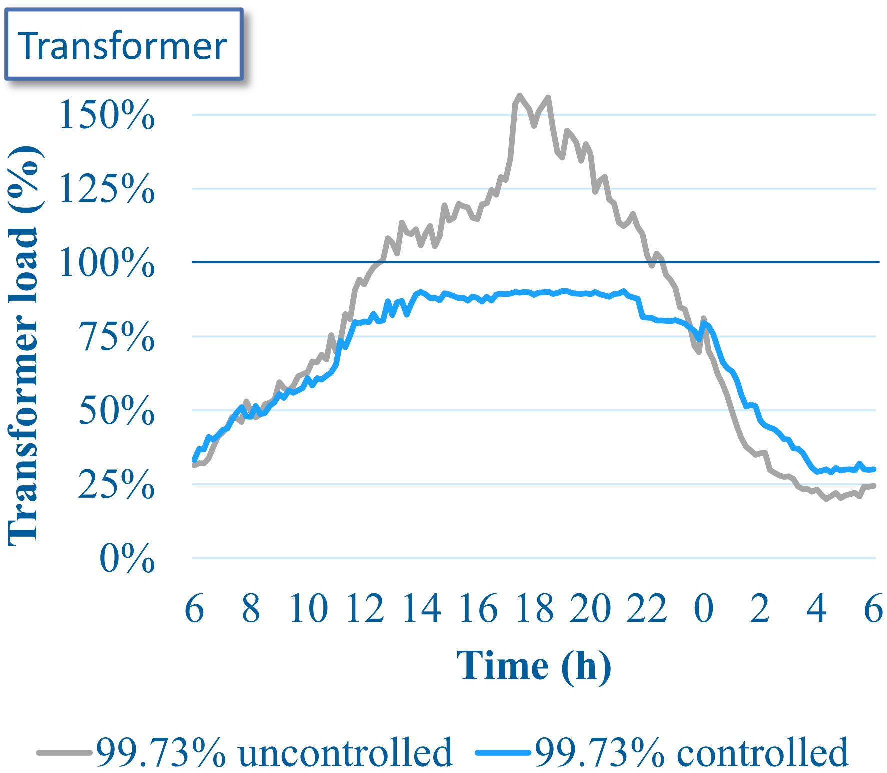
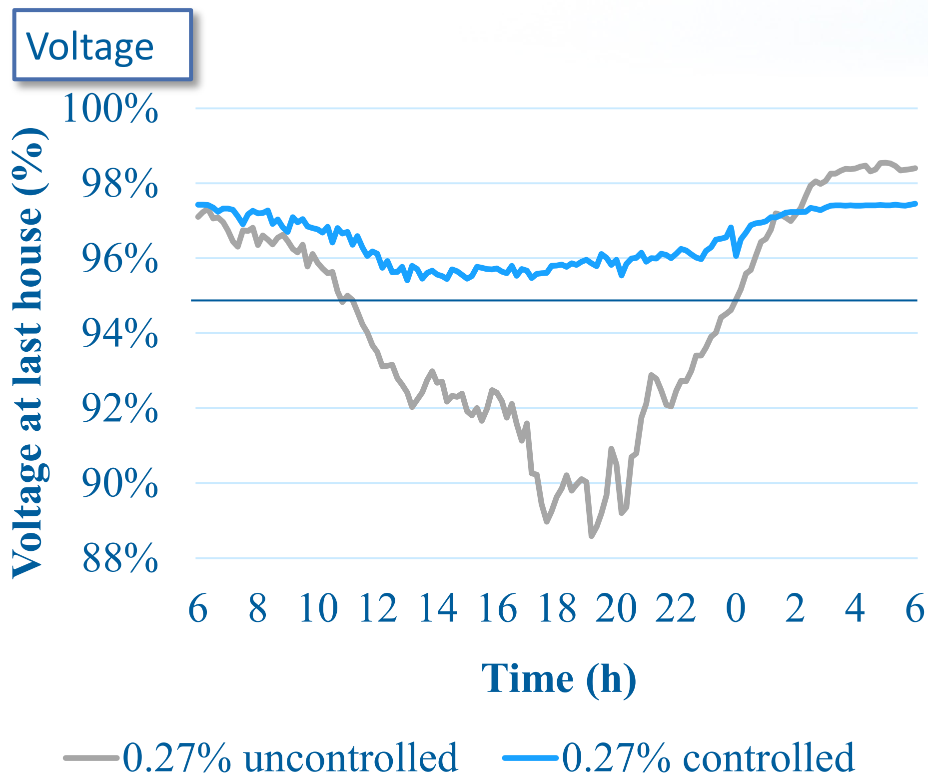
## Controlled vs. Uncontrolled Charging of 100% EV on weekdays

- 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:**

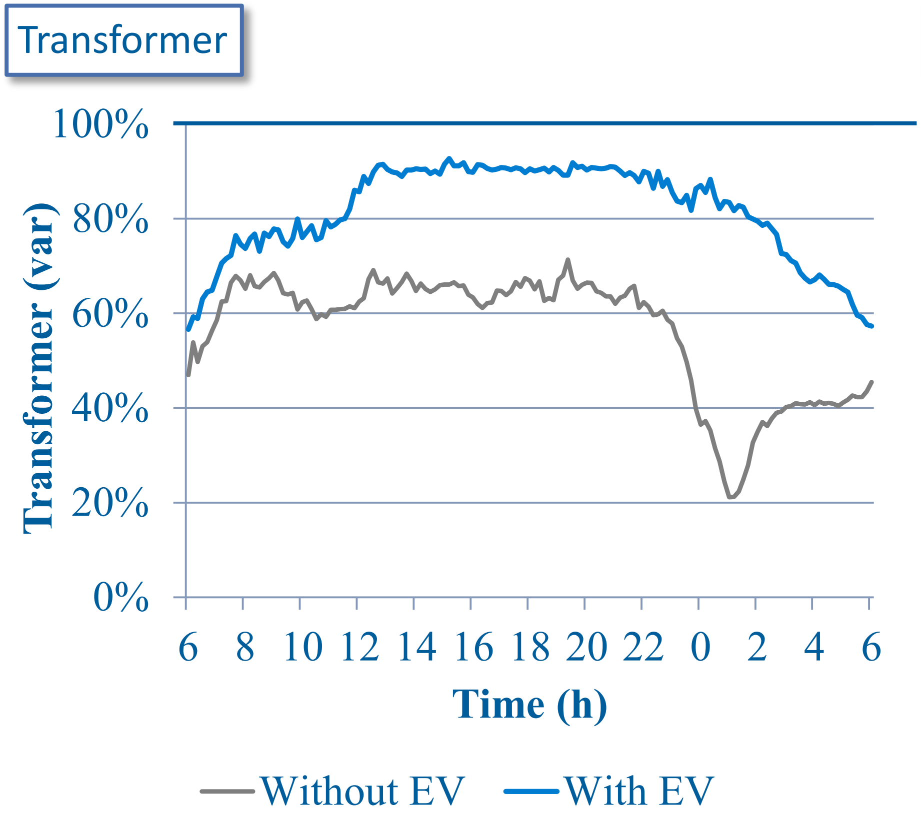
- Powerlines within boundaries
- No additional car owner restrictions
- 24% average charging power reduction (8.4 kW)
- Location dependency

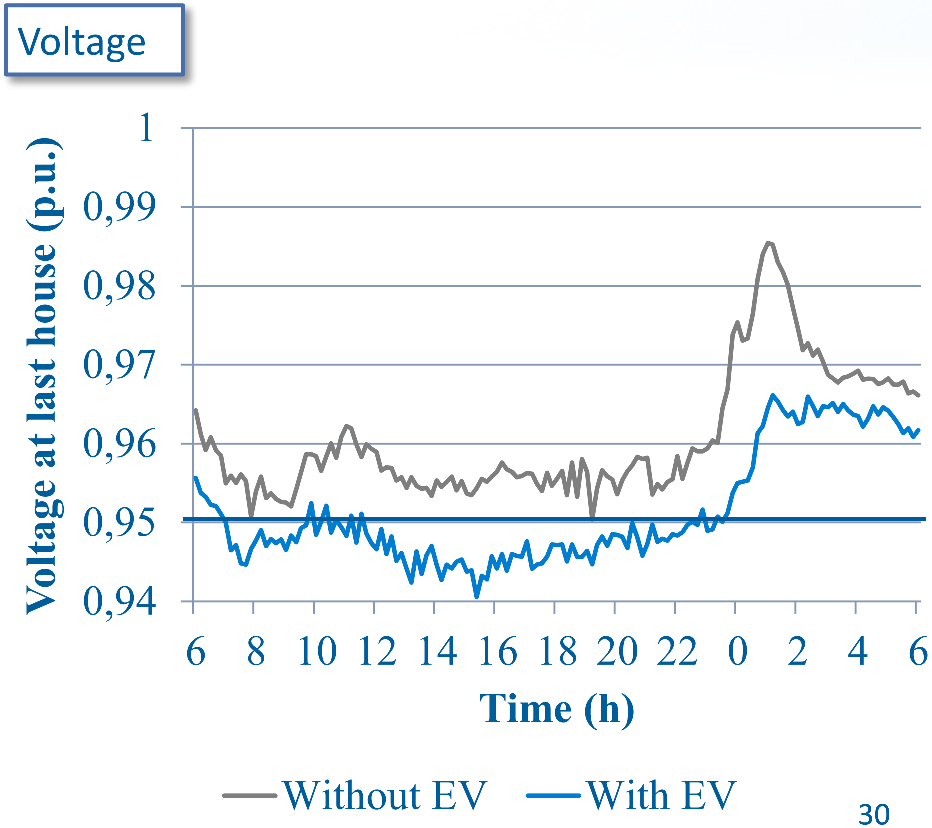
**Algorithm successful**

# 5. Simulation Results

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

- **Grid close to voltage boundary**



# 5. Simulation Results

**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)**

**Grid expansion**

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

- **Cloudy Sky; Night**

# 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

## 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

https://thenounproject.com/term/electric-bus/1288568/

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https://thenounproject.com/term/electric-car/725/