Swarm Grids – Distributed power grid control for distributed renewable power generation

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Technology
Arts Sciences
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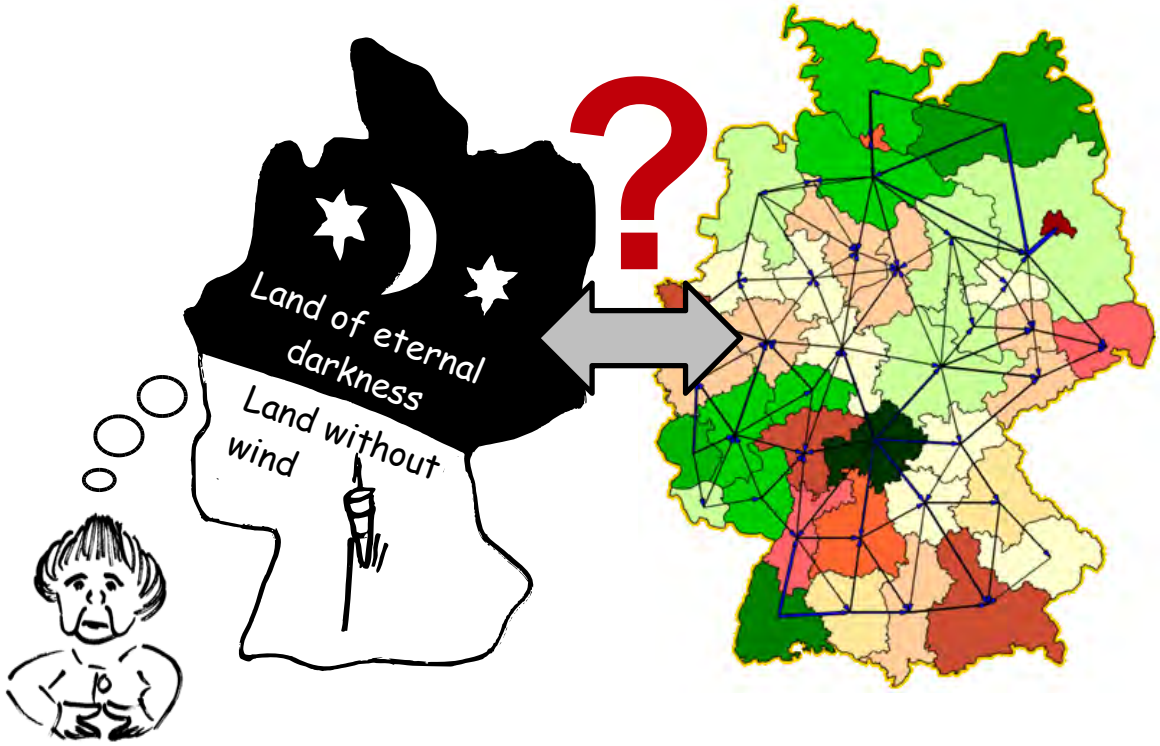
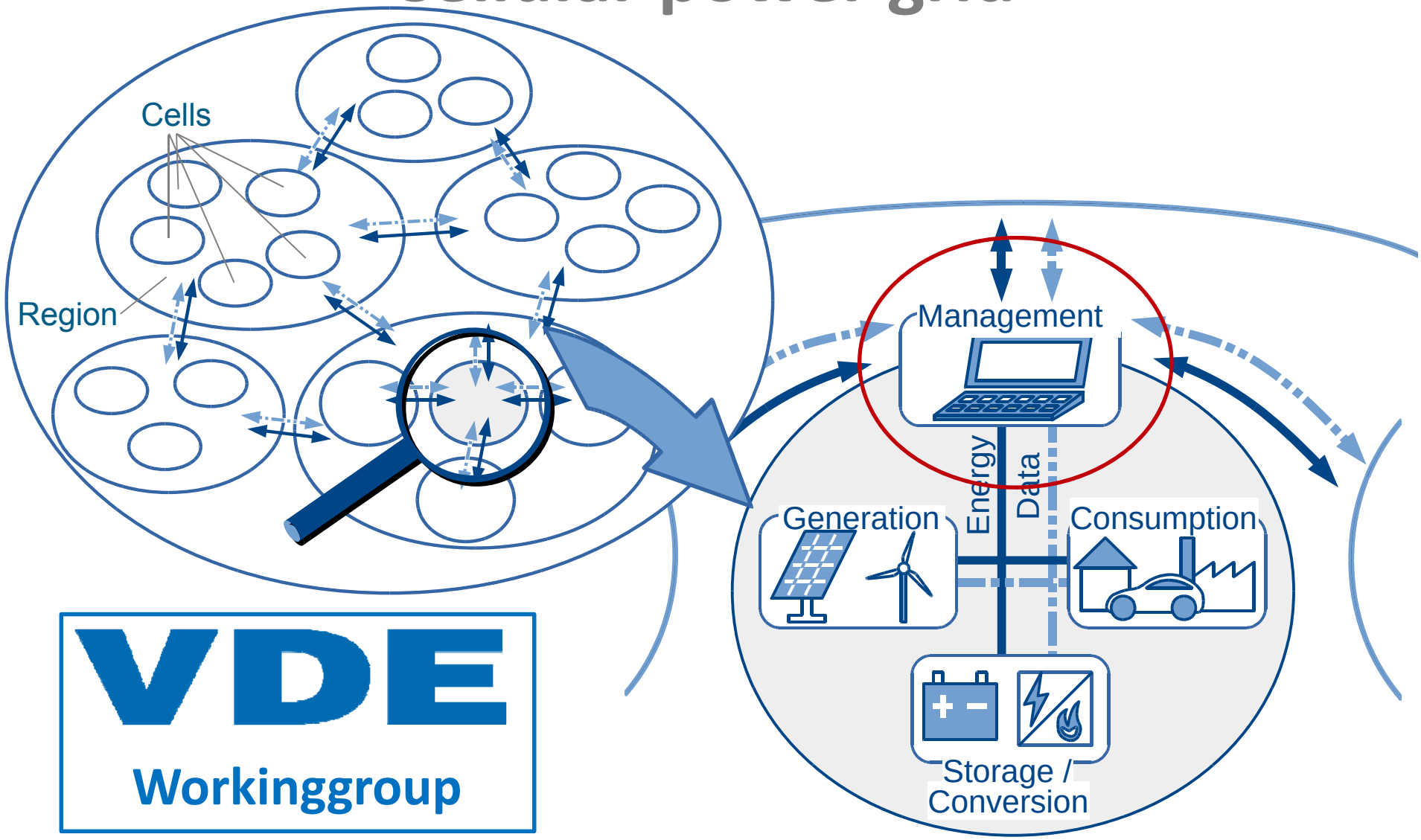
Future grid structure



Celluar power grid:

- Regionalized grid structure
- Decentralized power generation

Cellular power grid



VDE
Workinggroup

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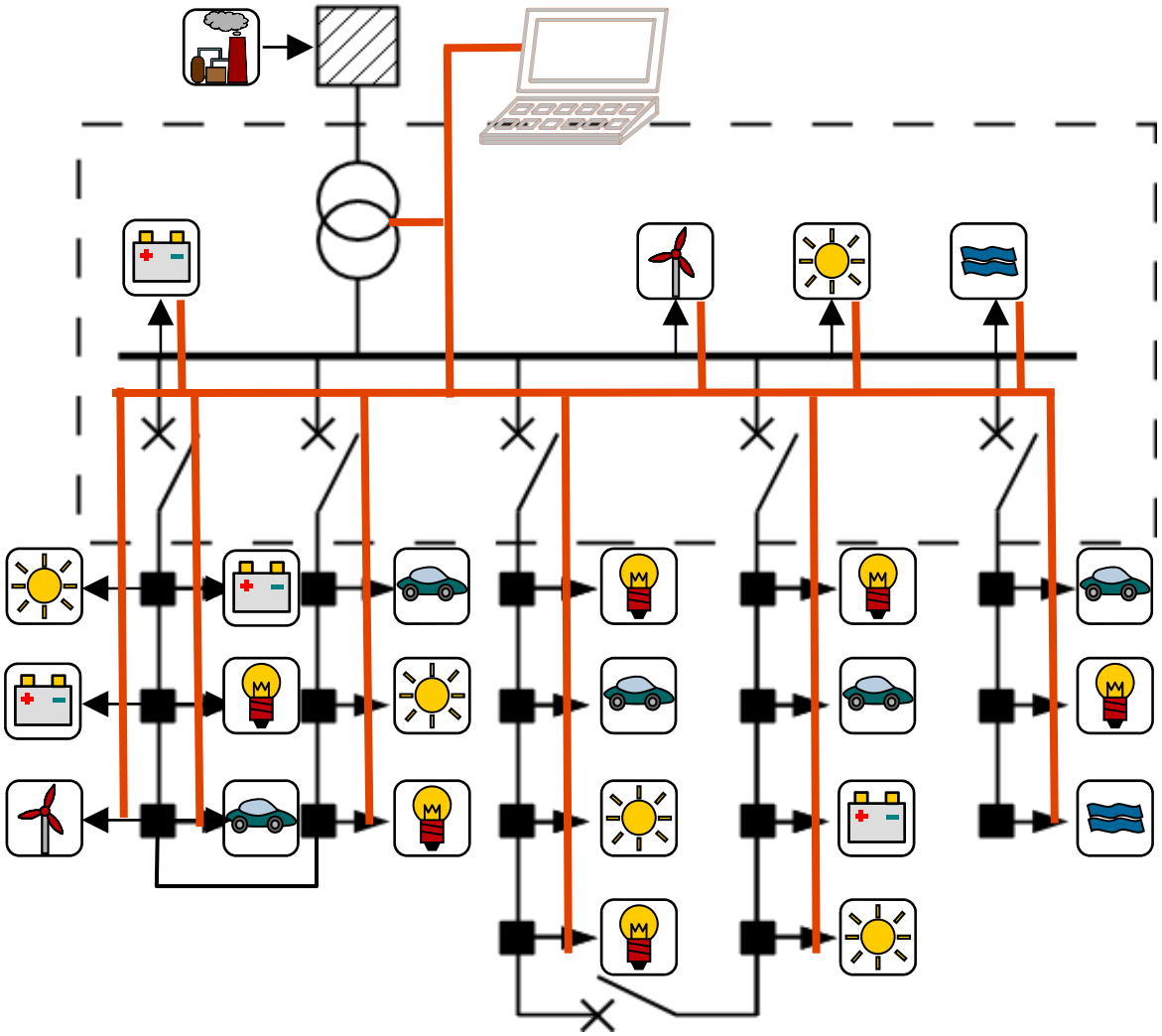
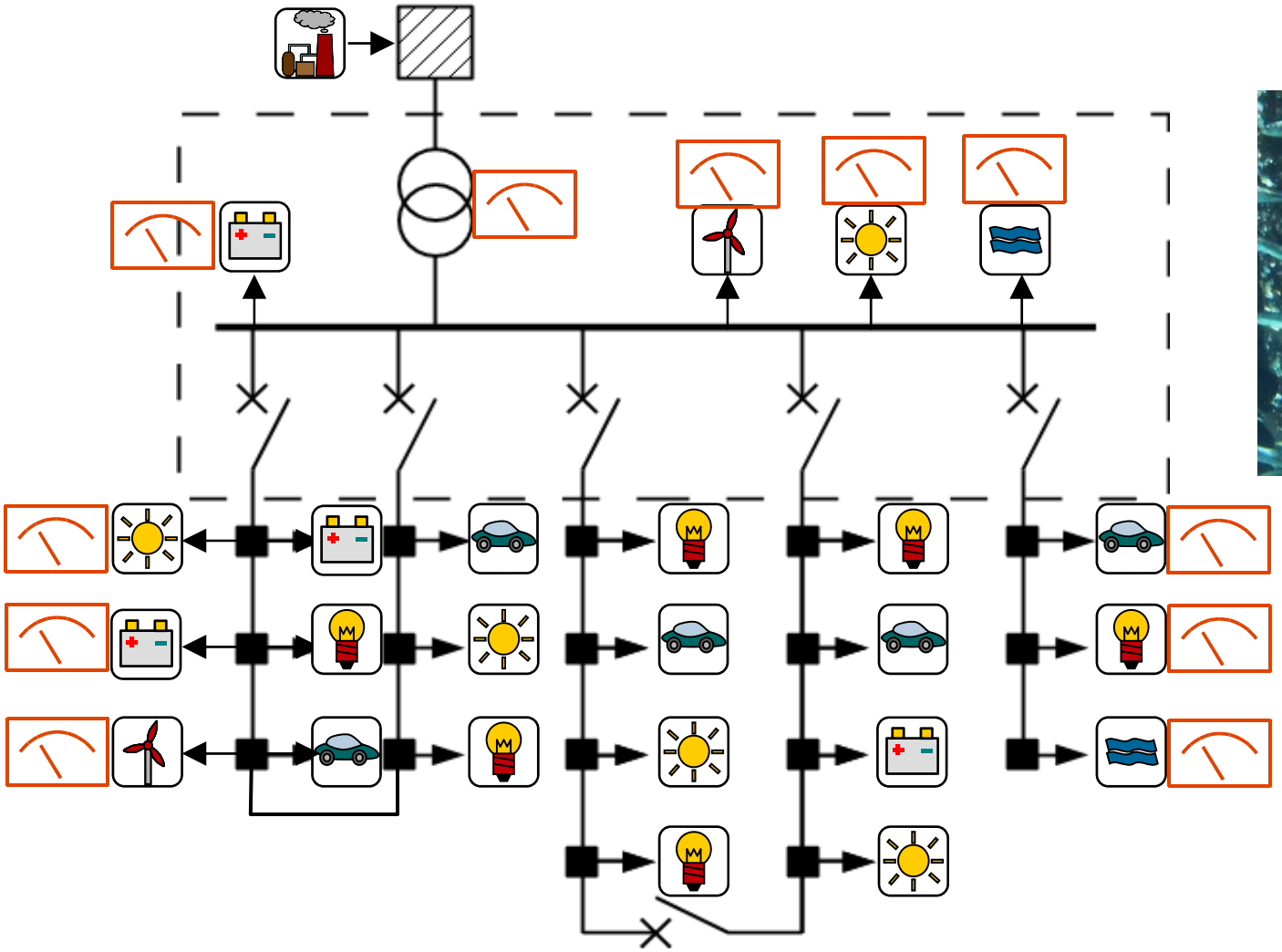
E. Waffenschmidt
2021

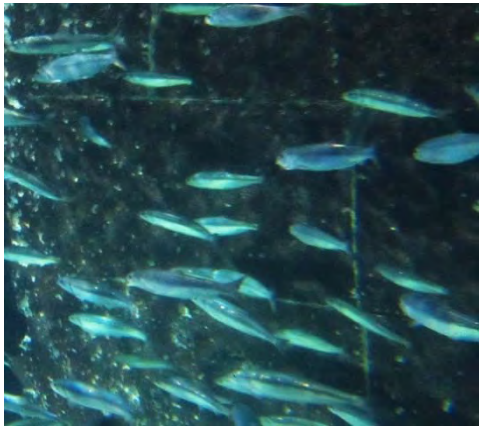
Graphik: E. Waffenschmidt
for working group
„Energieversorgung 4.0“ der ETG im VDE

What people consider as Smart-Grid:



Swarm-Grid instead of Smart-Grid:





Swarm principle:

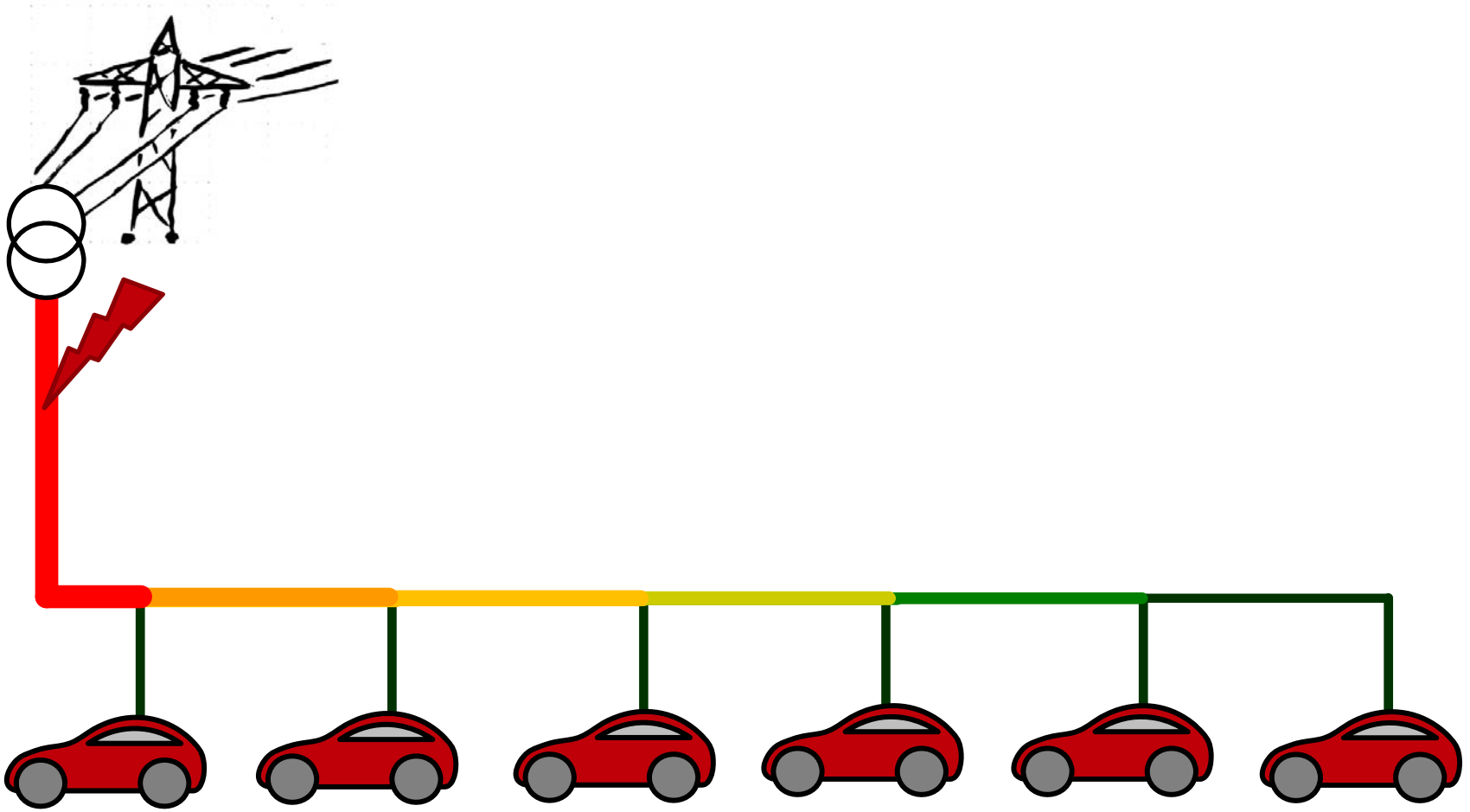
Mutual aim by

- Measurement
- Communication
- Reaction

Electrical consumption of electromobility

- Daily distance approx. 40 km
- Specific energy consumption approx 15 kWh/100km
- All cars electric in Germany:
  - *Energy need approx.* 17% of today's energy consumption
  - *Power*:
    40Mio x 20 kW = 800GW
    Exceeds today's peak demand by far.

Load of a power line



Distributed arrival

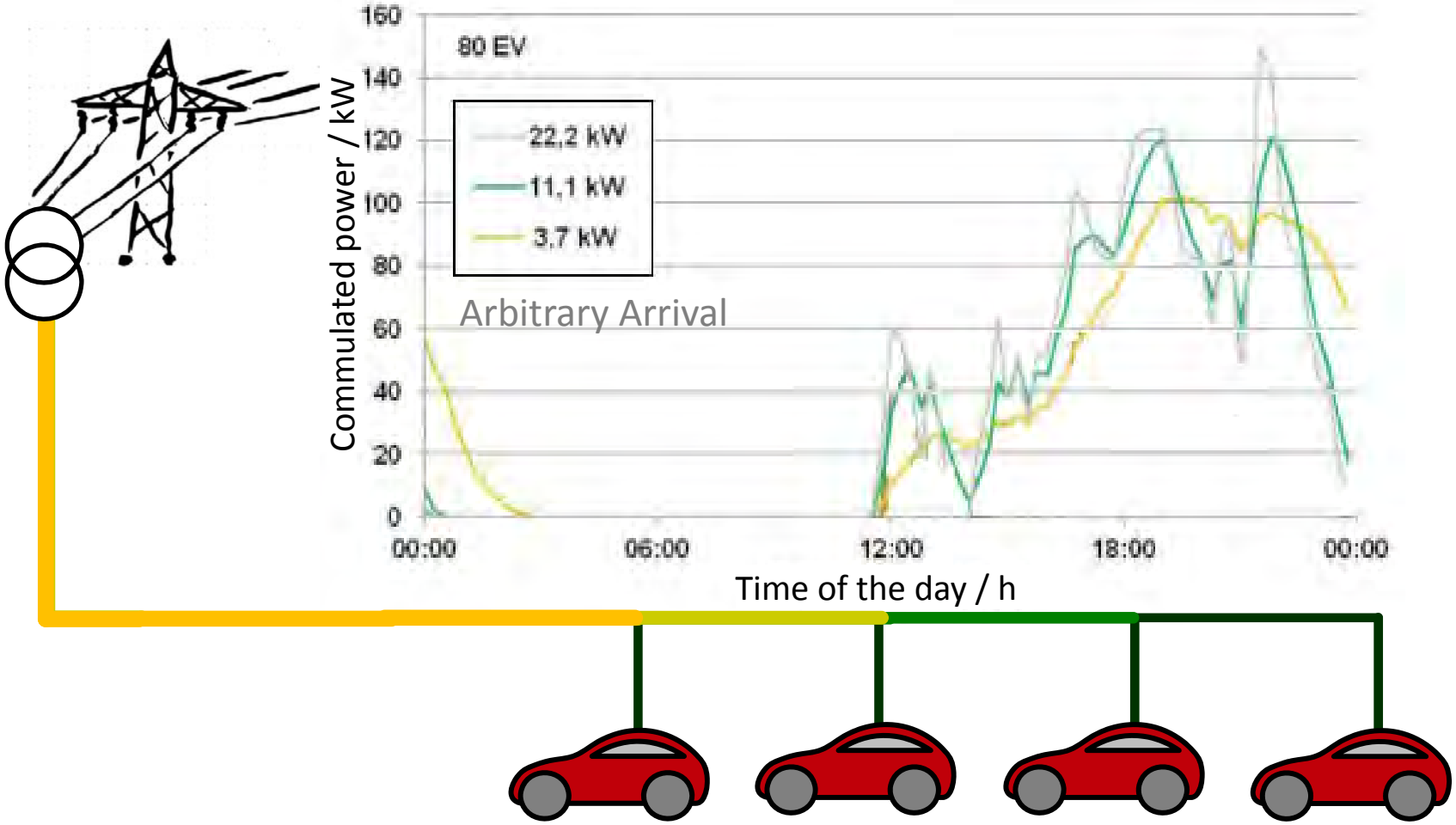


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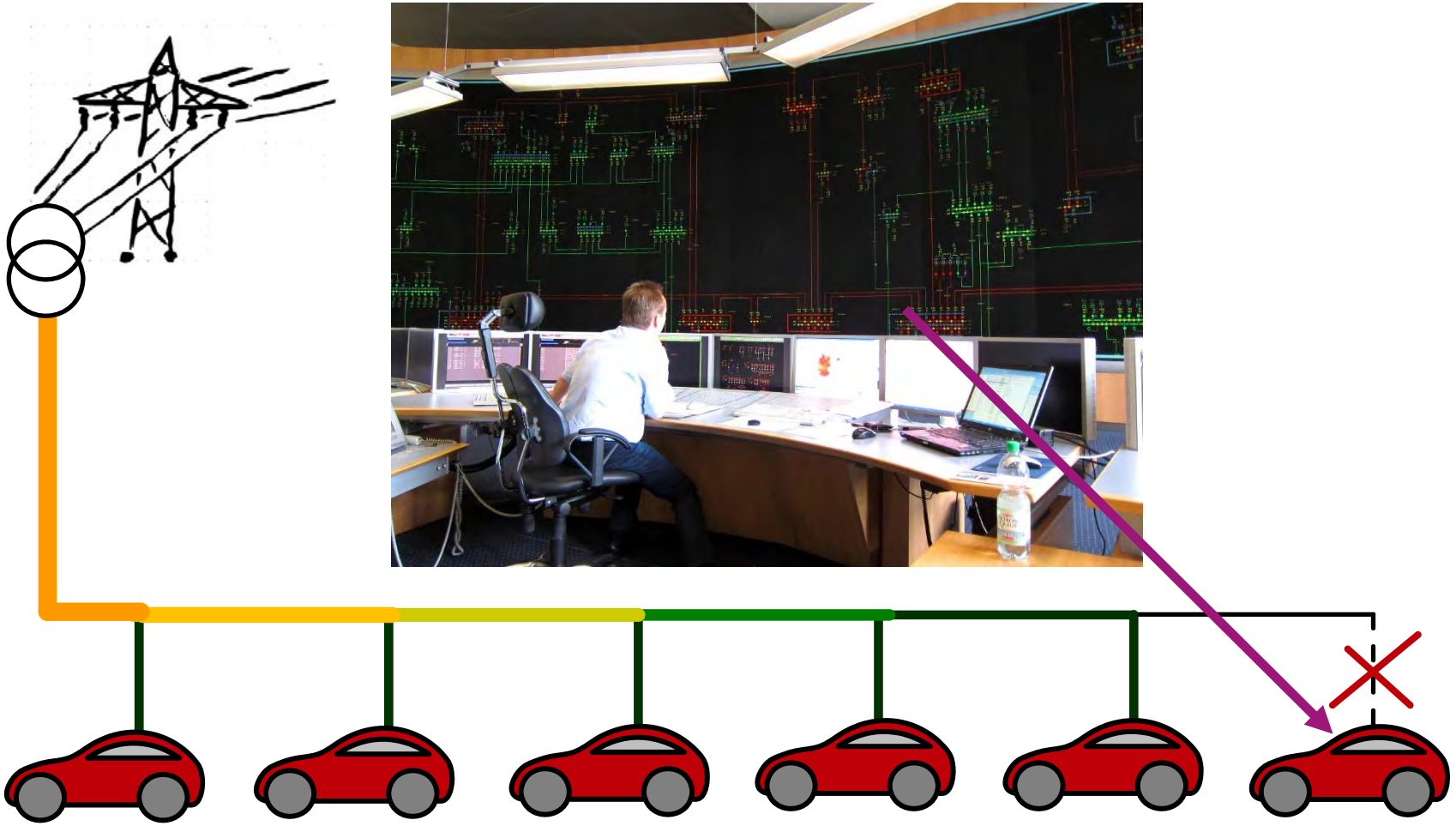
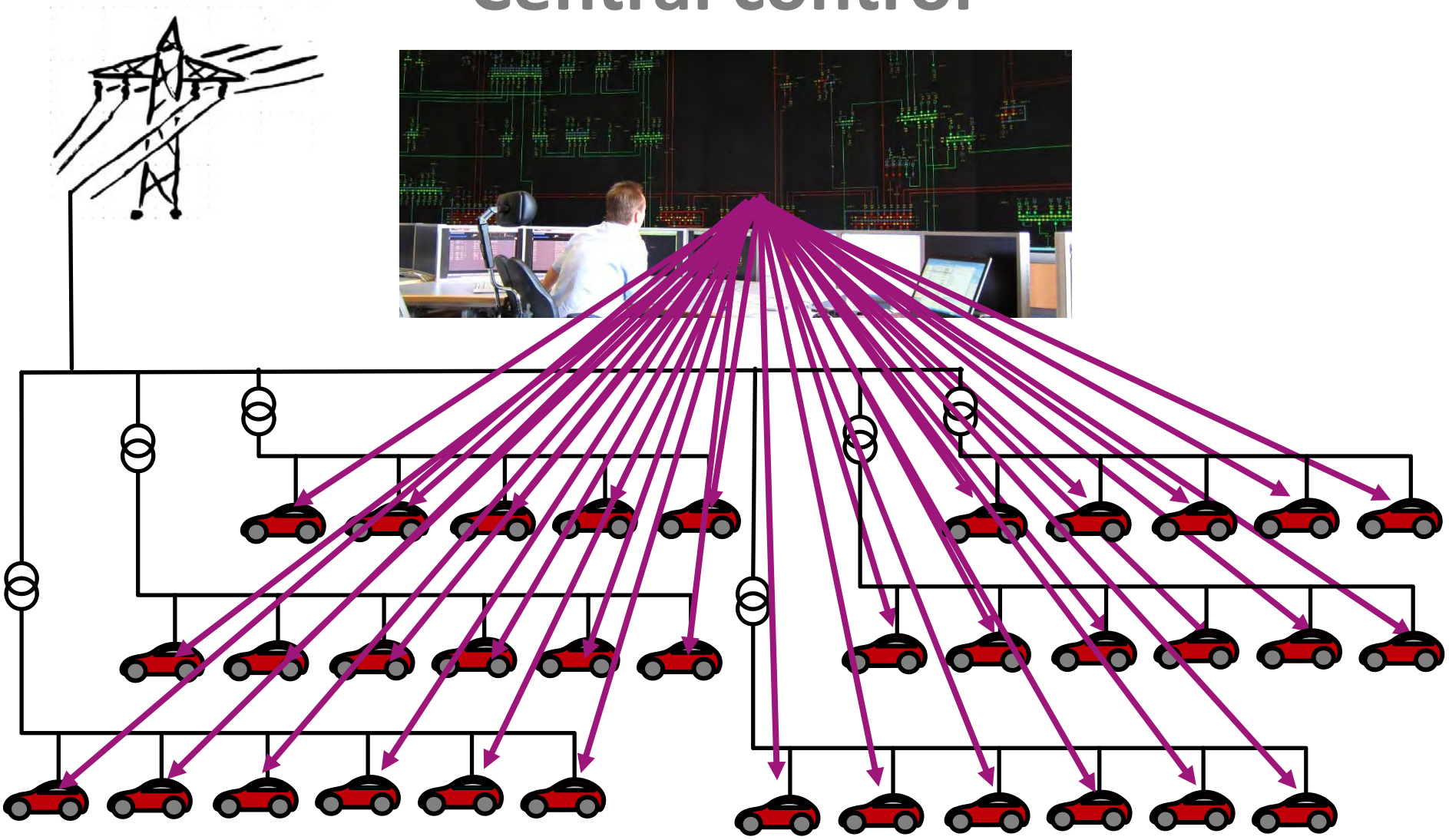
Diagram: T. Doum et al. TH-Köln 2017, http://www.100pro-erneuerbare.com/netze/publikationen/2015-06-Doum/Doum-Lastmanagement_Elektromobilitaet.htm.

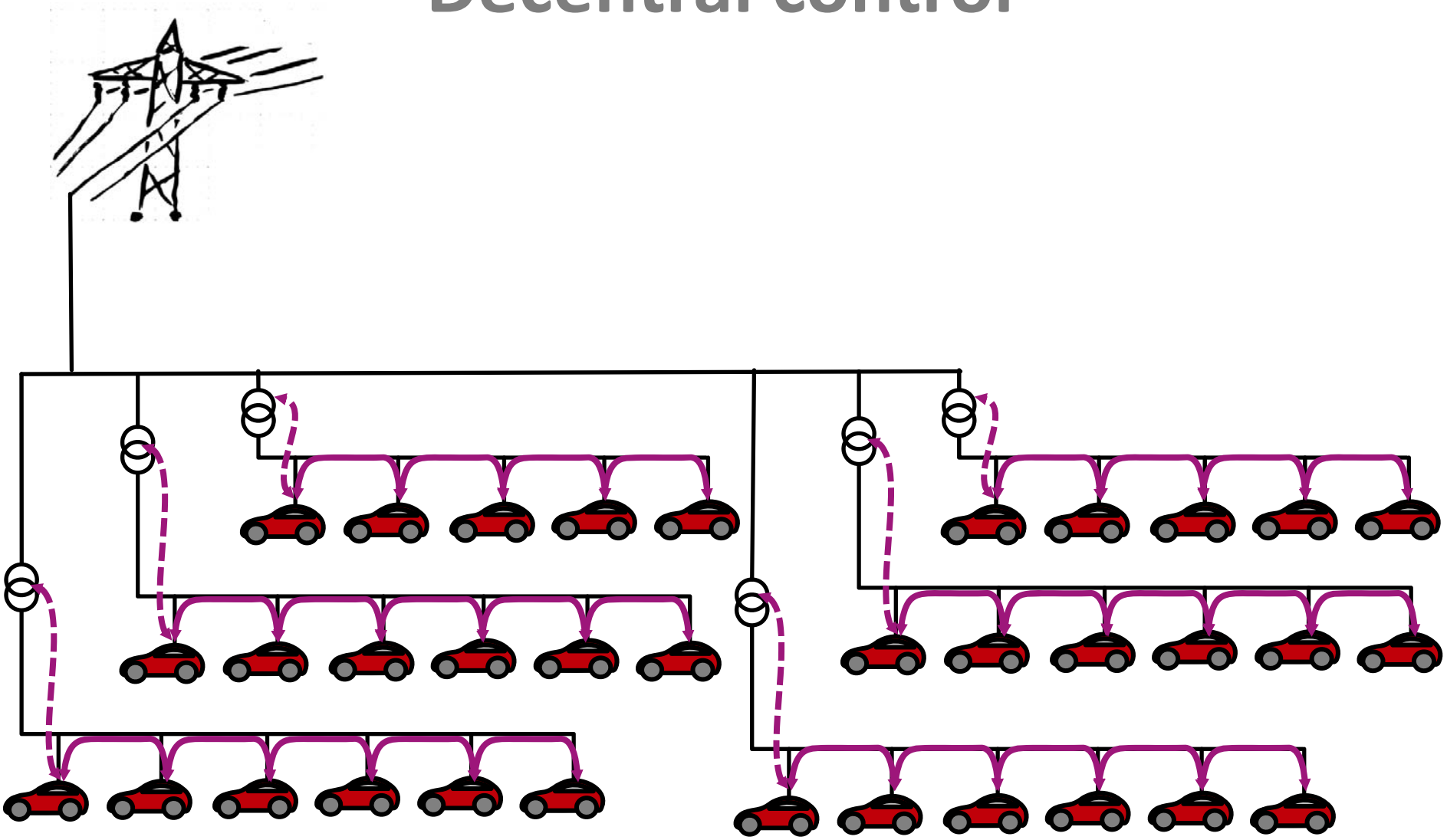
Central control



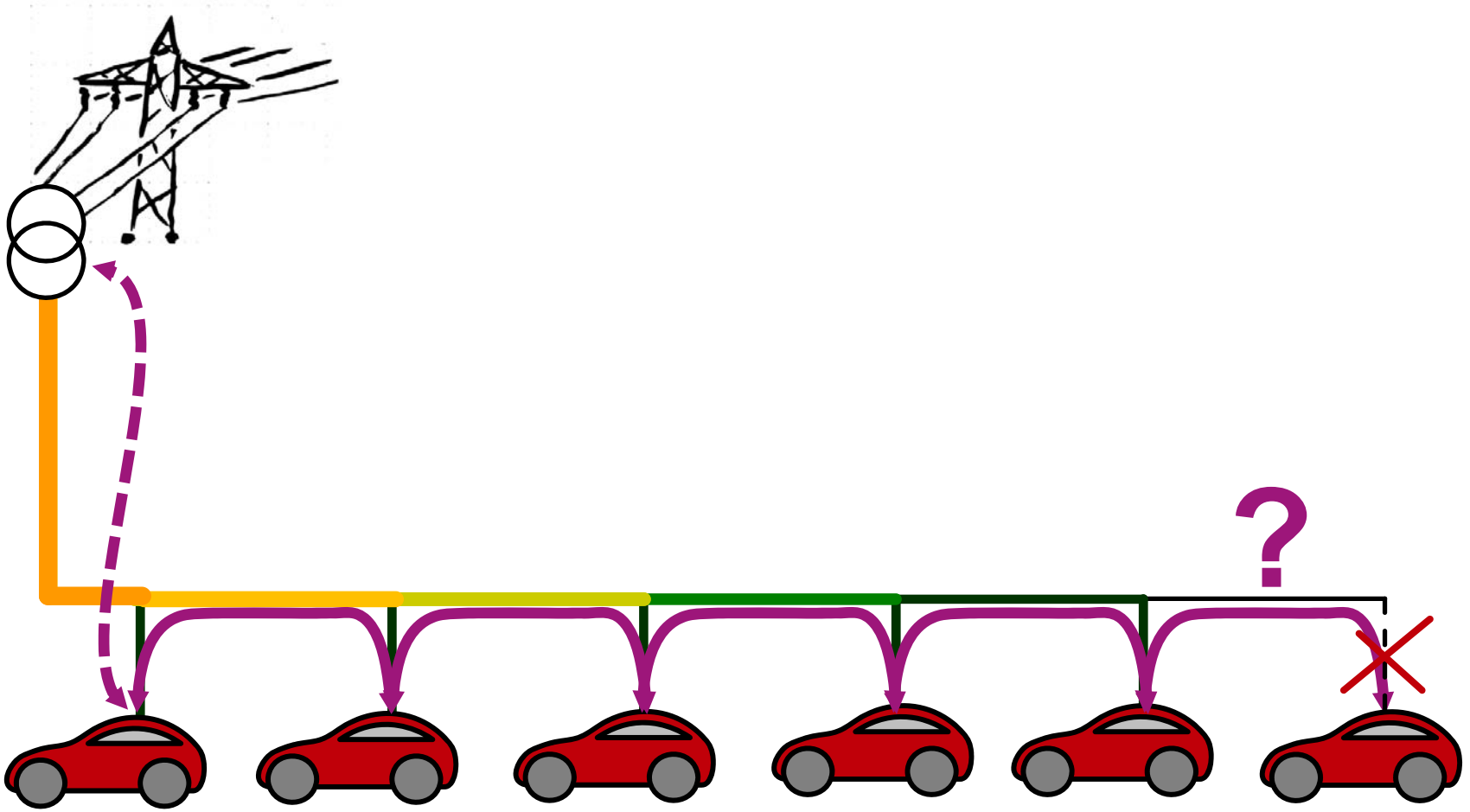
Central control



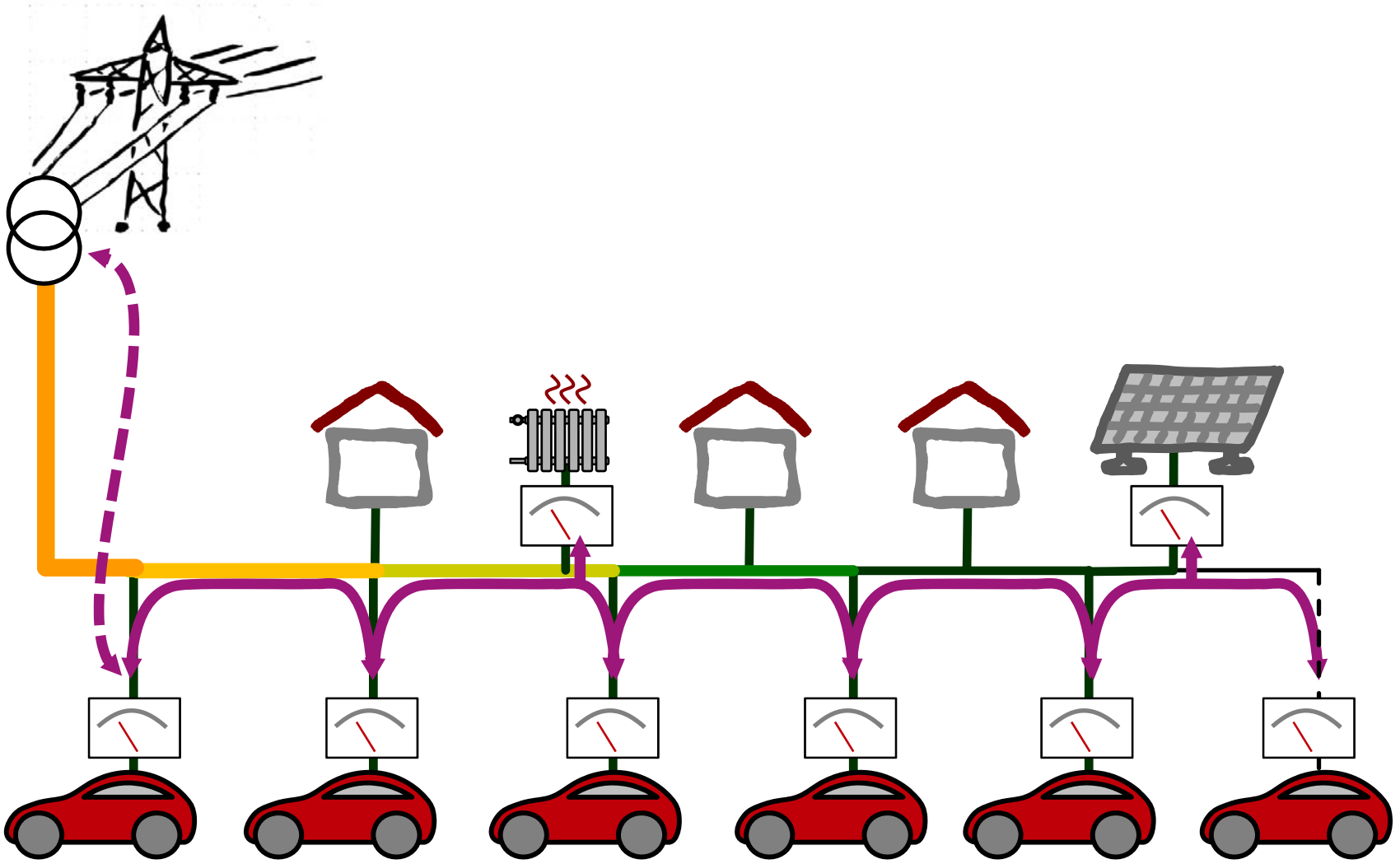
Decentral control



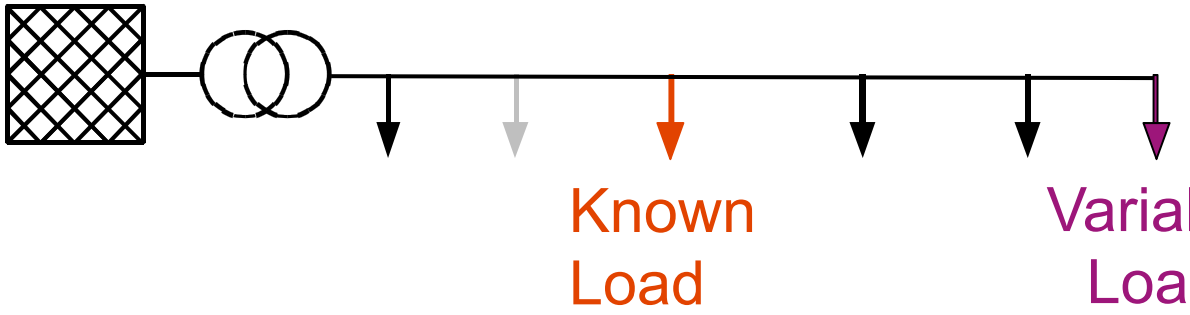
Decentral control



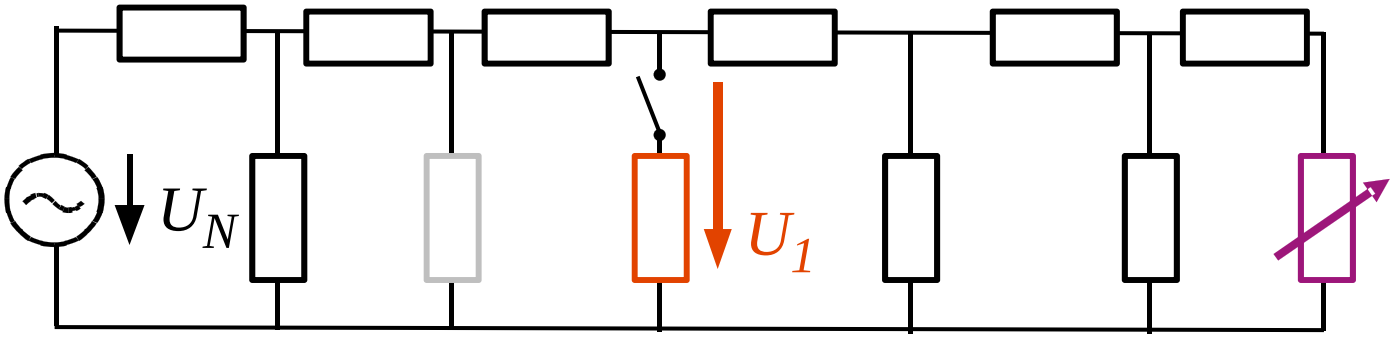
Decentral control



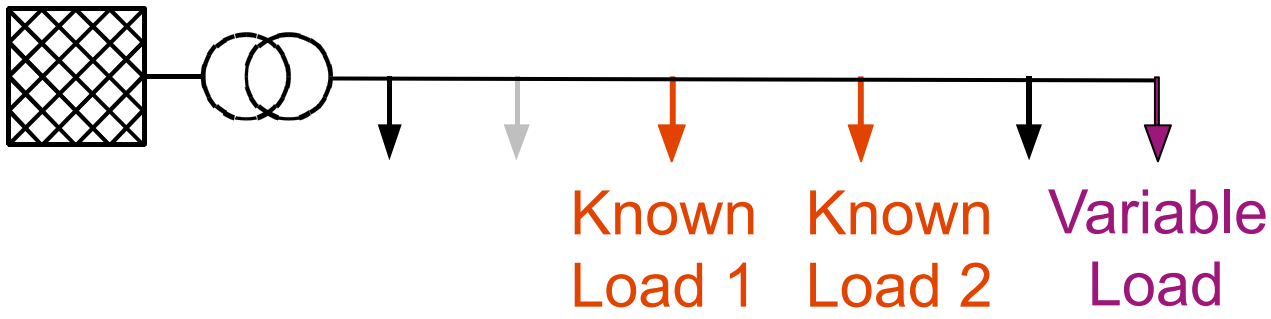
Single node measurement



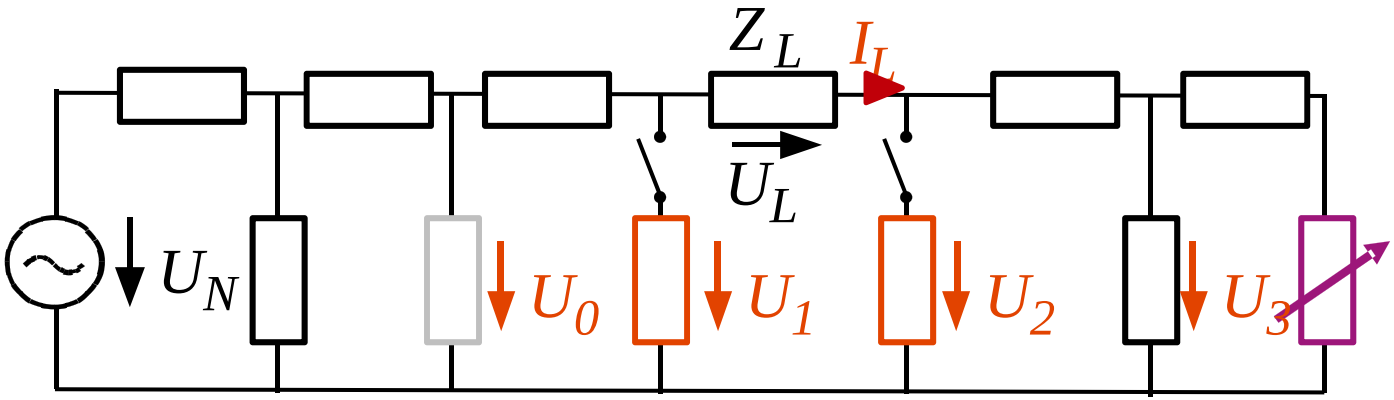
- Only node voltage
- No currents
- No further nodes



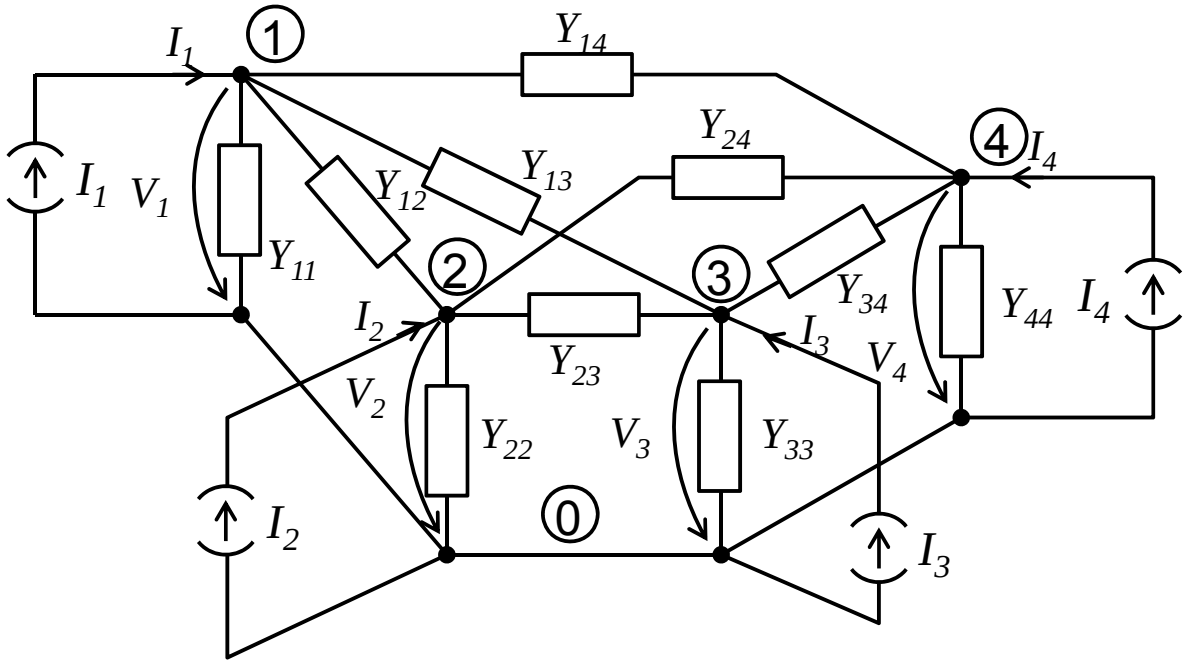
Coordinated grid state measurement



- More node voltages
- Line currents
- Topoplgy estimation



Nodal potential method

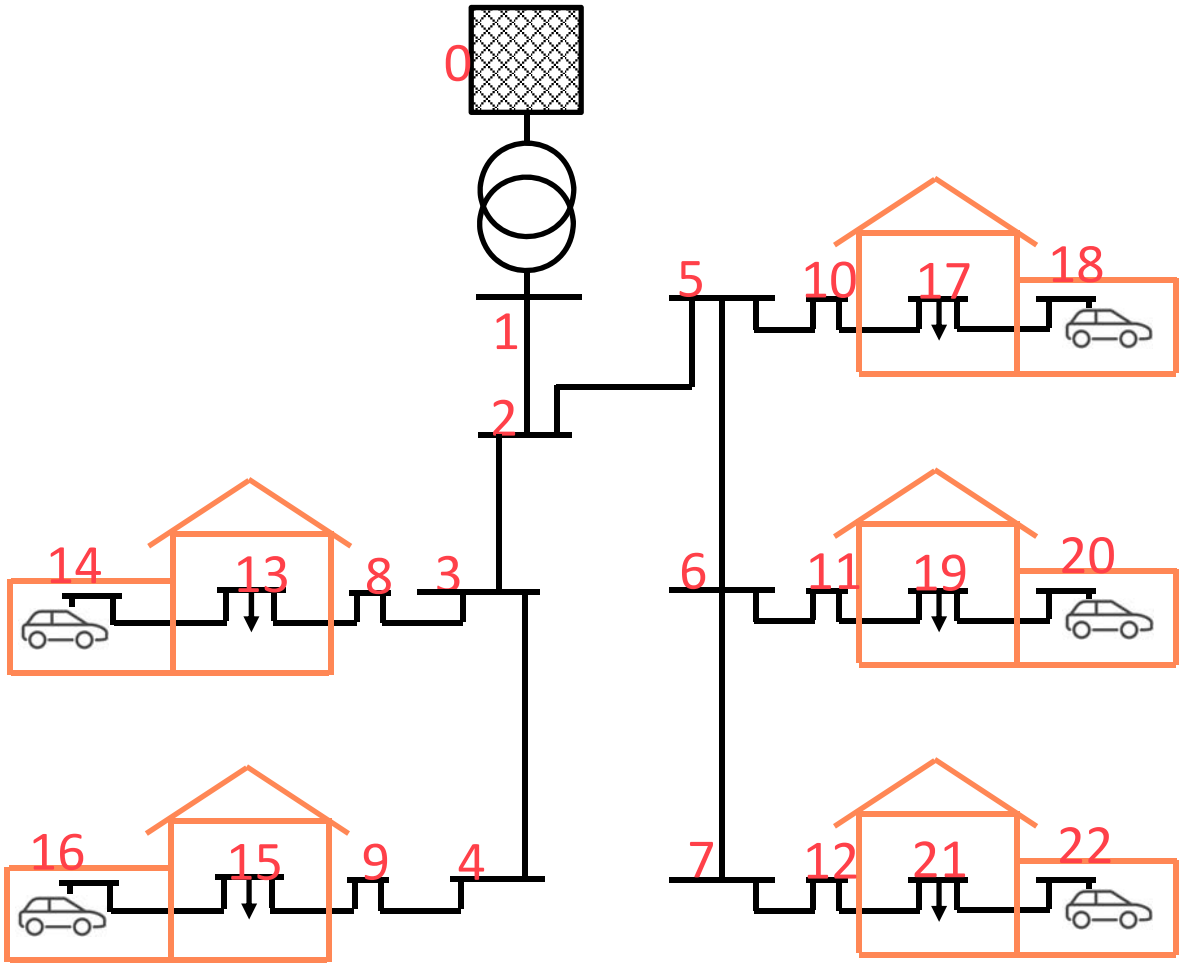


$$\begin{pmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \cdot \begin{pmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{pmatrix}$$

- For more than 2 nodes
- Retrieves currents from voltages
- Re-arranging of equaltion system:
- Current and voltages at unmeasured nodes

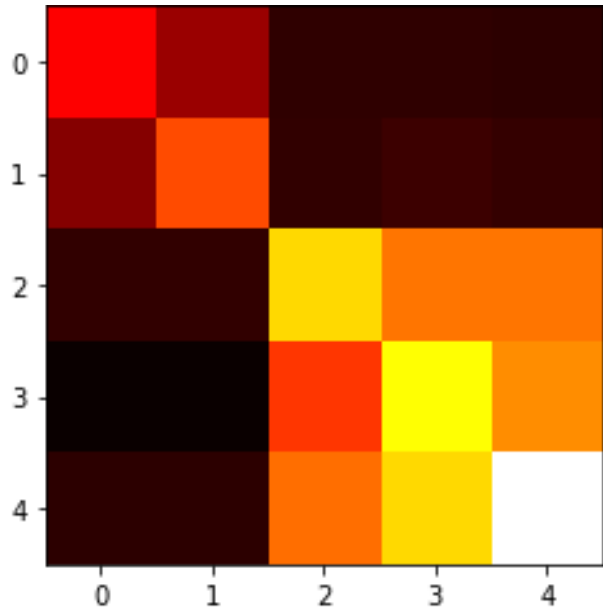
Grid topology estimation

Exemplary test grid



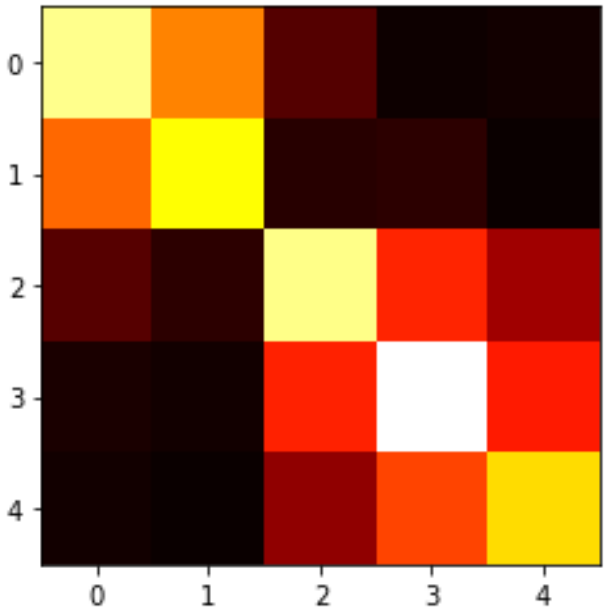
Grid topology estimation

1. **Voltage measurements with defined current steps**



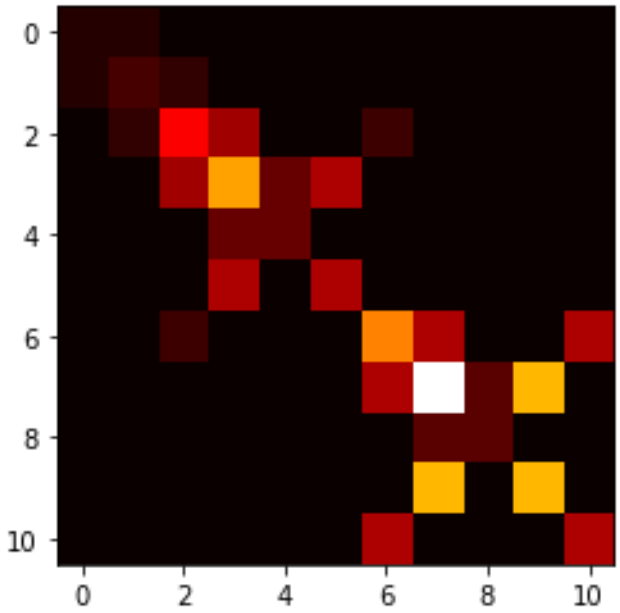
- Switch known loads (e.g. charging stations)
- Measure voltage change at all known nodes.

2. **Admittance matrix for known nodes**



- Determine matrix coefficients from voltages and currents
- For general grid topology

3. **Admittance matrix for additional nodes**



- Assume star-like topolgy
- Determine branch nodes

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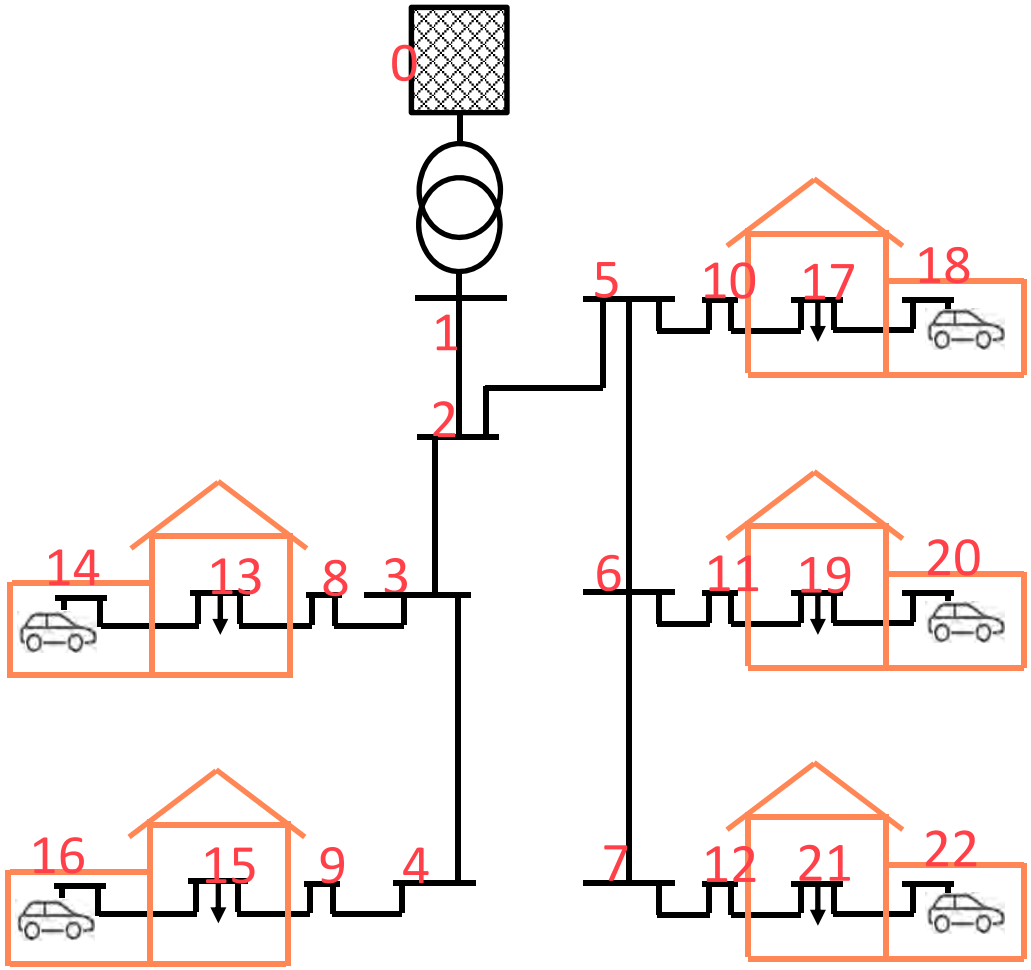
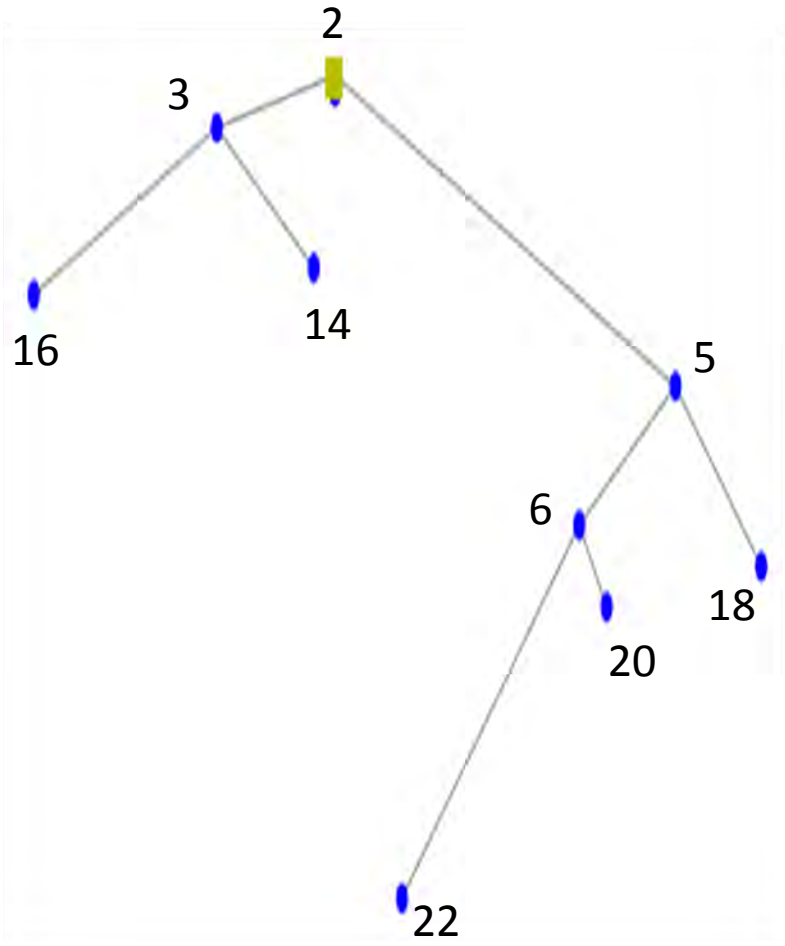
Graphics by Christian Hotz TH-Köln 2021

Grid topology estimation

Original power grid

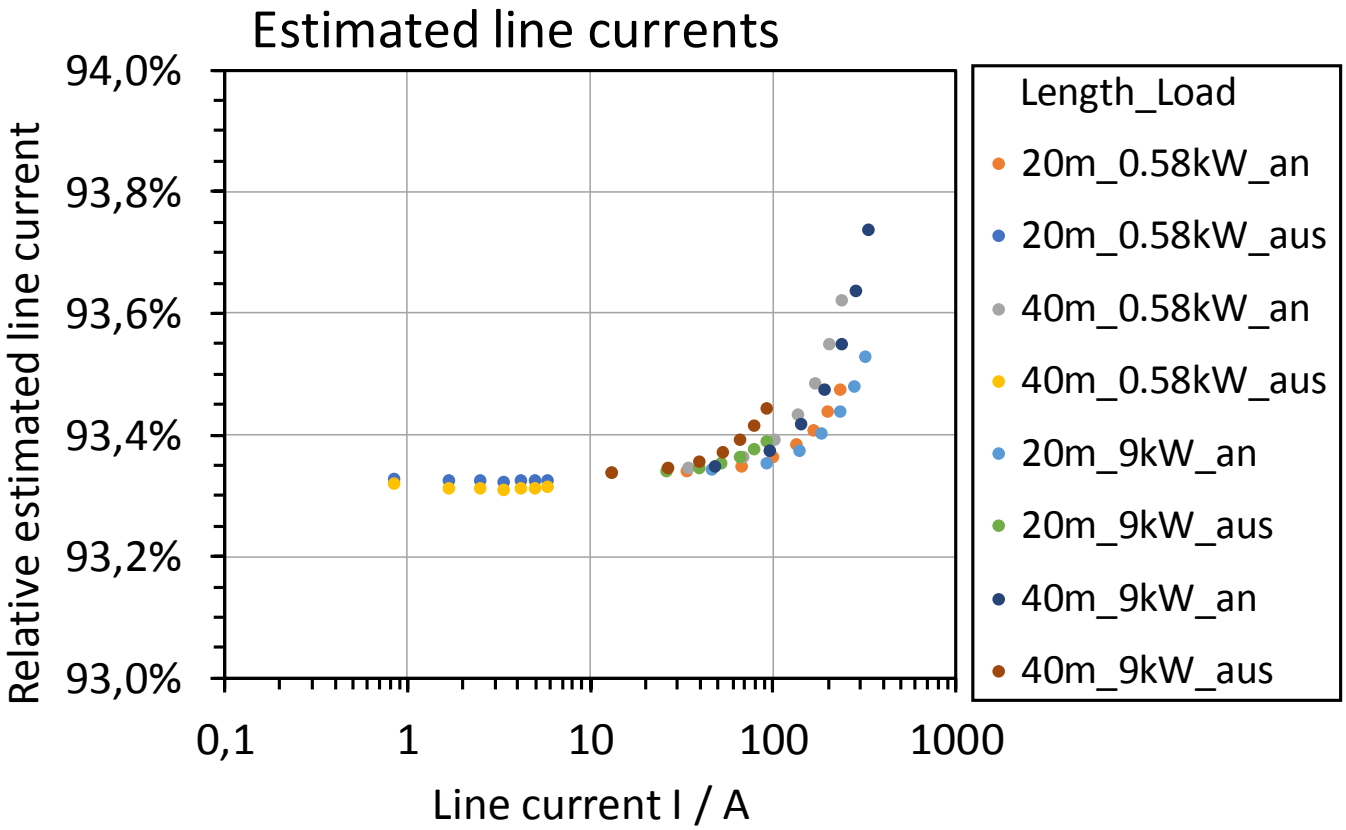


Determined grid topoplogy



Line current estimation

Example for an exemplary typical grid



Precision depends on

- Voltage measurement
- Power factor
- Further nodes

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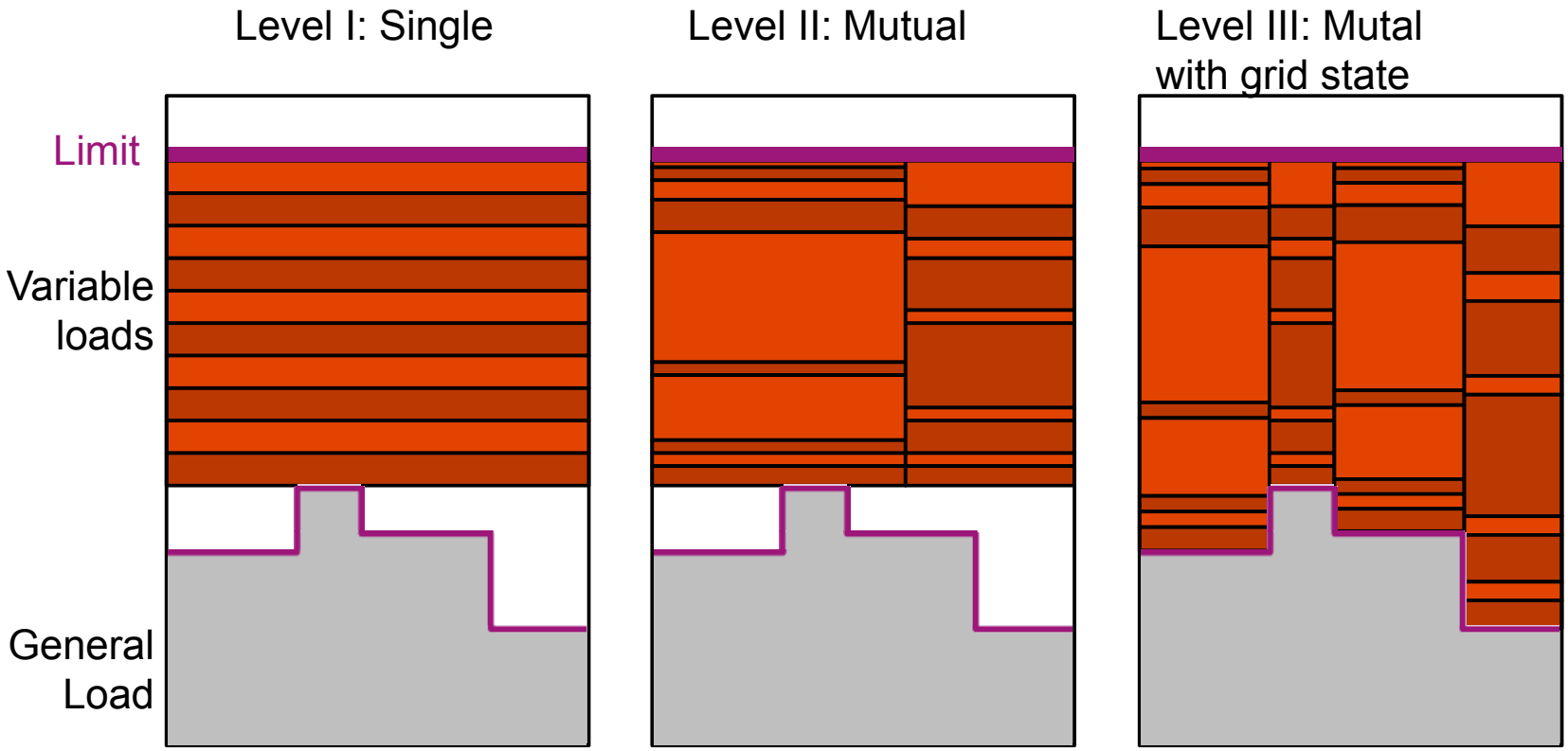
Diagram and results by Phillip Schaaf, TH-Köln 2021

Three level control

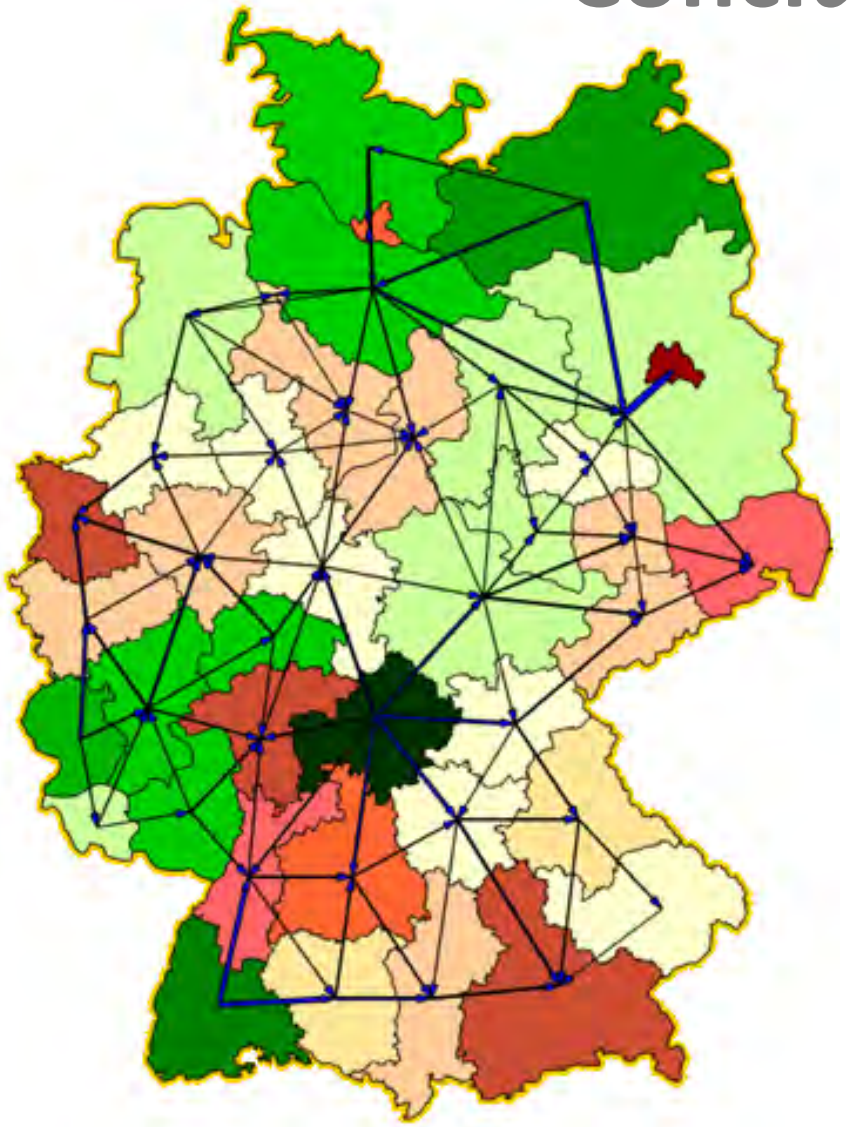


- Single safe power budget
- No Communication

- Mutual fixed power budget
- Distribution by demand
- Communitation of devices

- Mutual variable power budget
- Determination of the actual grid state
- Communication of devices

Conclusion



- Decentralized grid structure for a decentralized power generation
- Cellular power grids according to the swarm principle
- Reduces need for power grid extension

Contact and further information

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