Swarm Grids – Distributed power grid control

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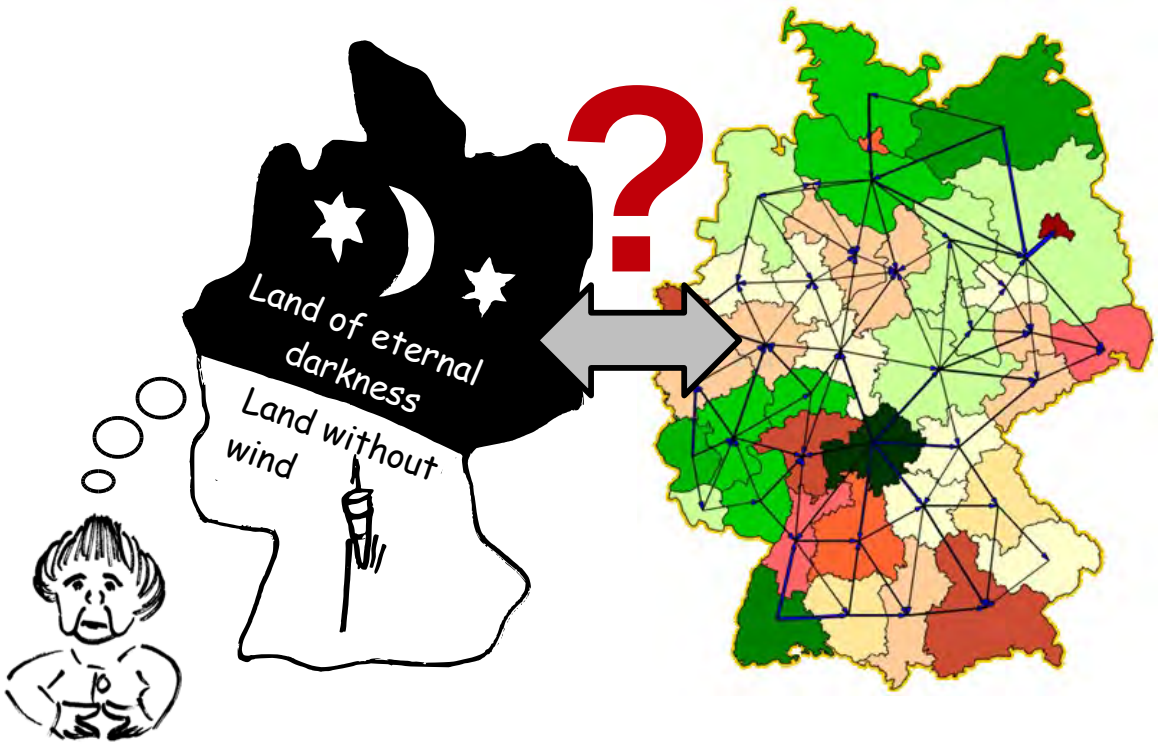
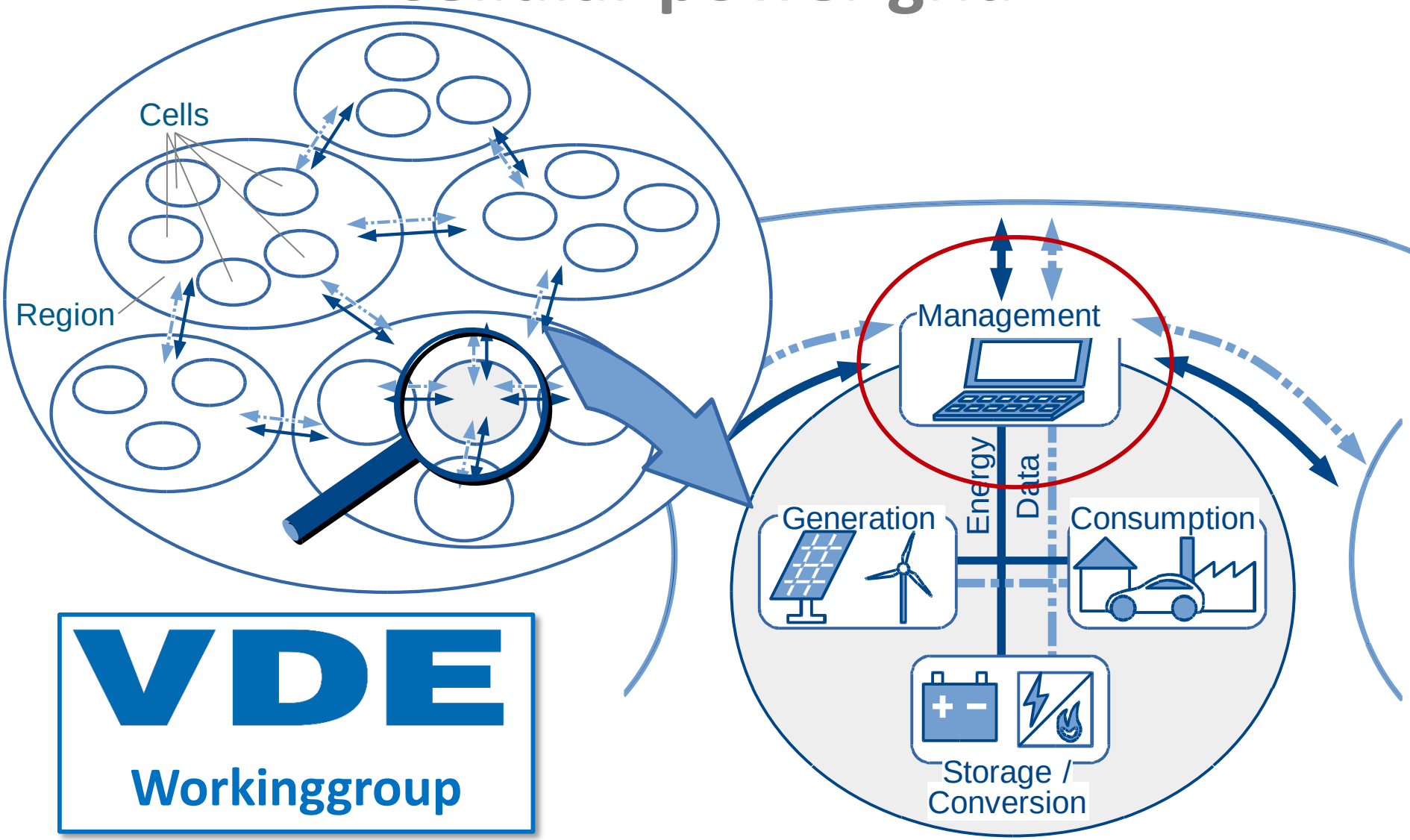
Future grid structure



Celluar power grid:

- Regionalized grid structure
- Decentralized power generation

Cellular power grid



VDE
Workinggroup

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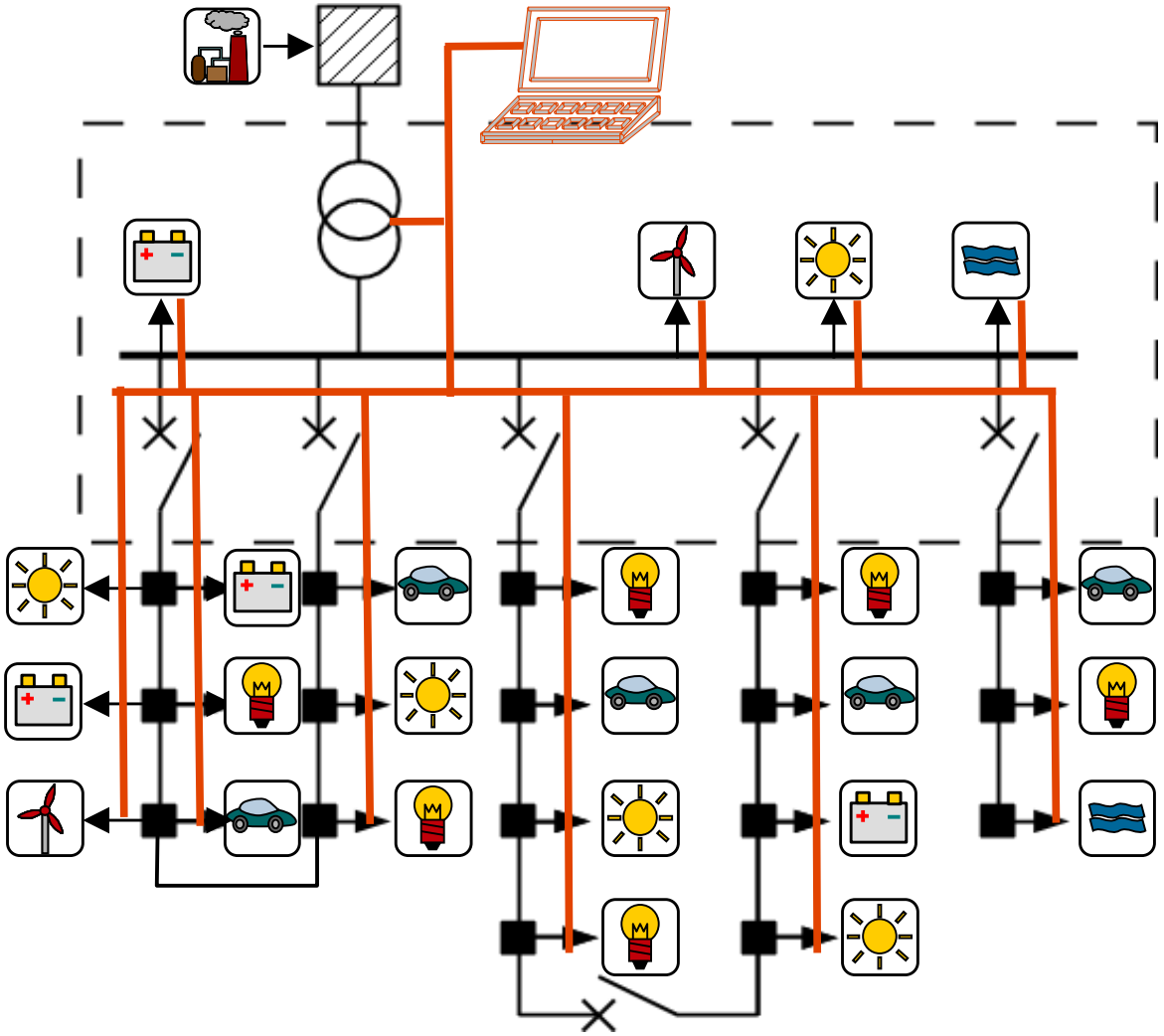
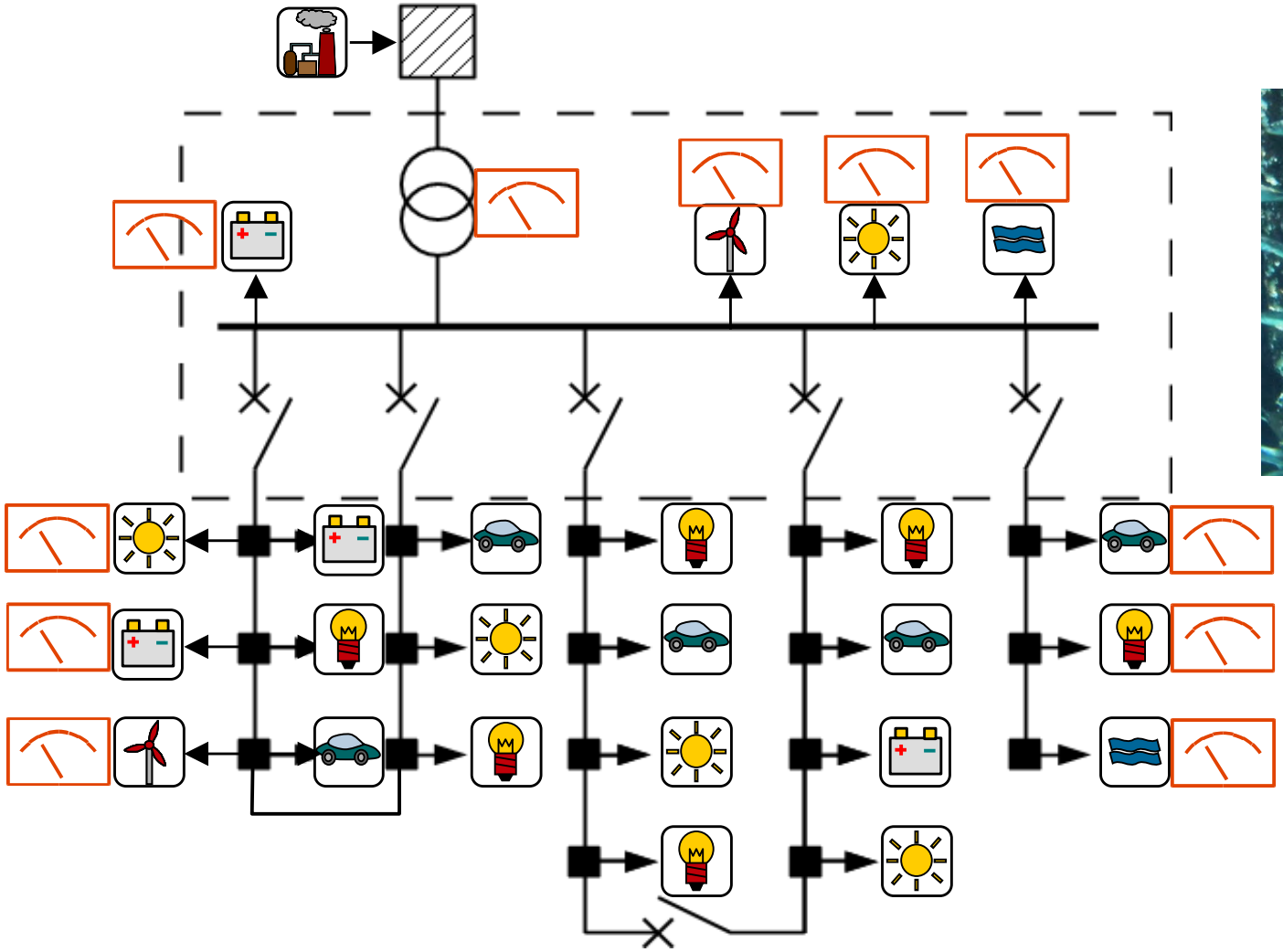
2024

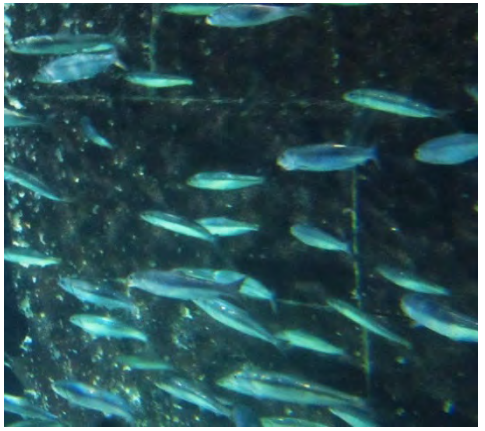
Graphik: E. Waffenschmidt
for working group
„Energieversorgung 4.0“ der ETG im VDE

What people consider as Smart-Grid:



Swarm-Grid instead of Smart-Grid:





Swarm principle:

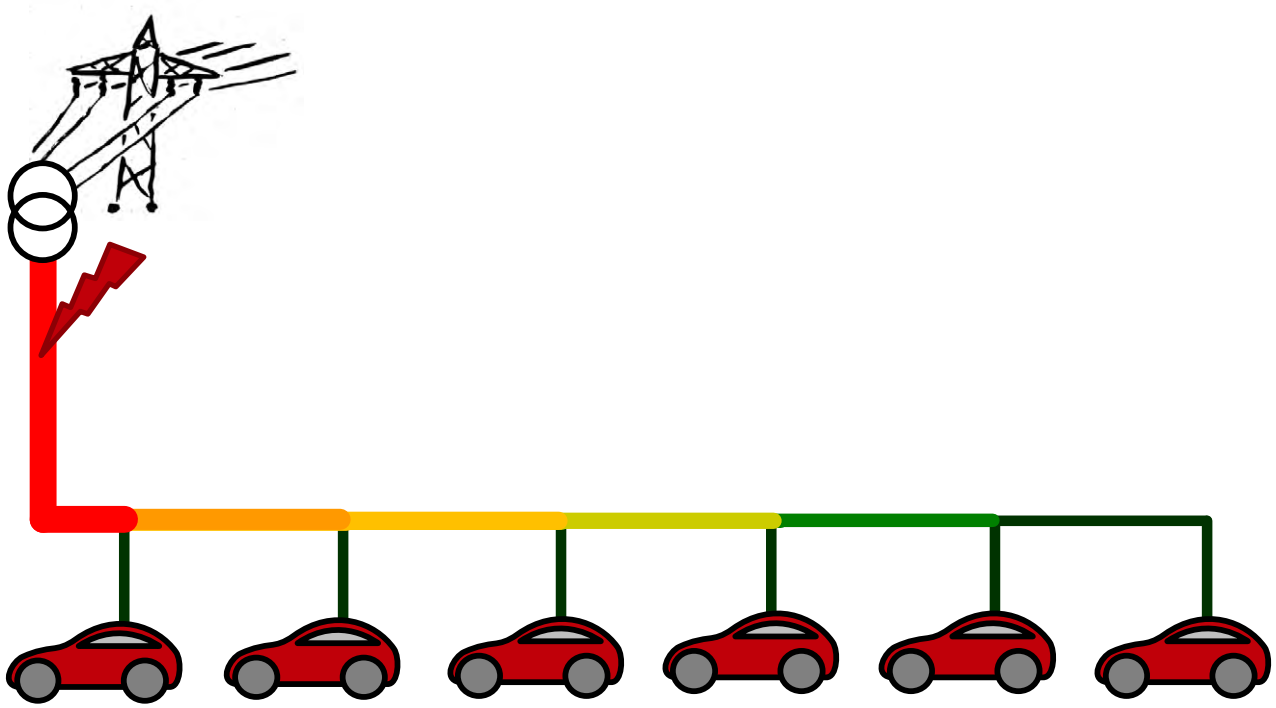
Mutual aim by

- Measurement
- Communication
- Reaction

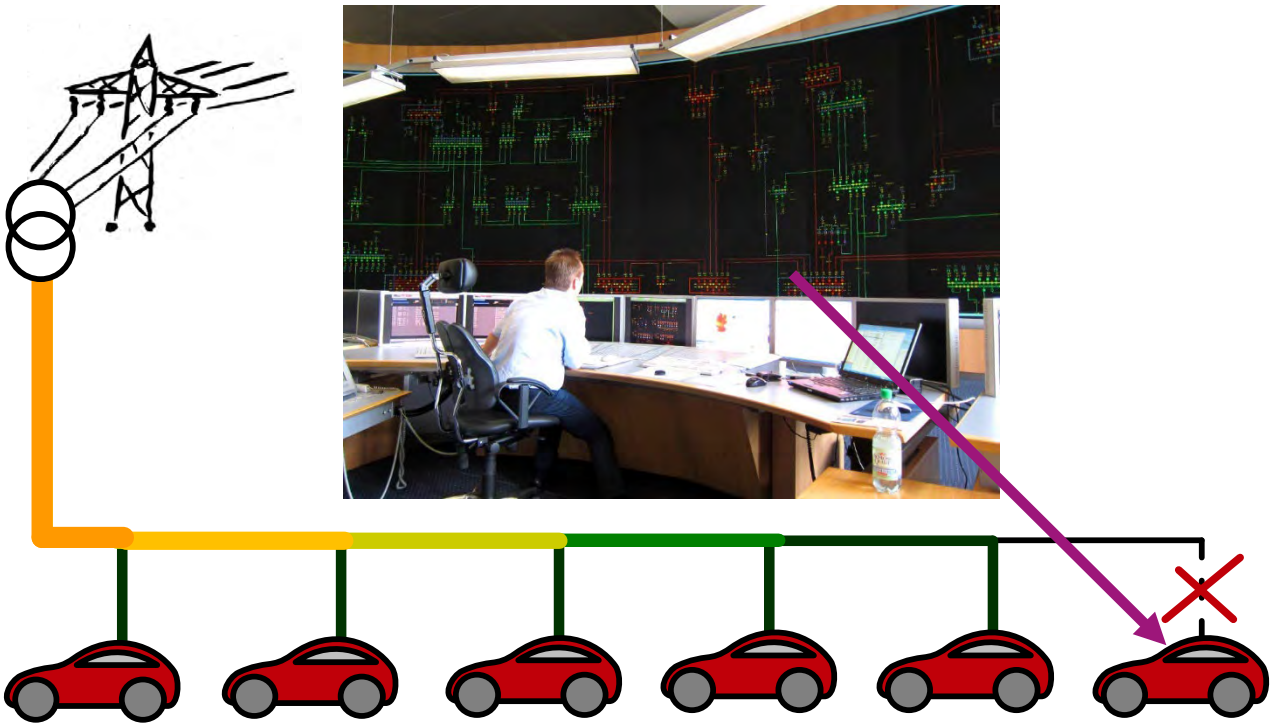
Electrical consumption of electromobility

- 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.

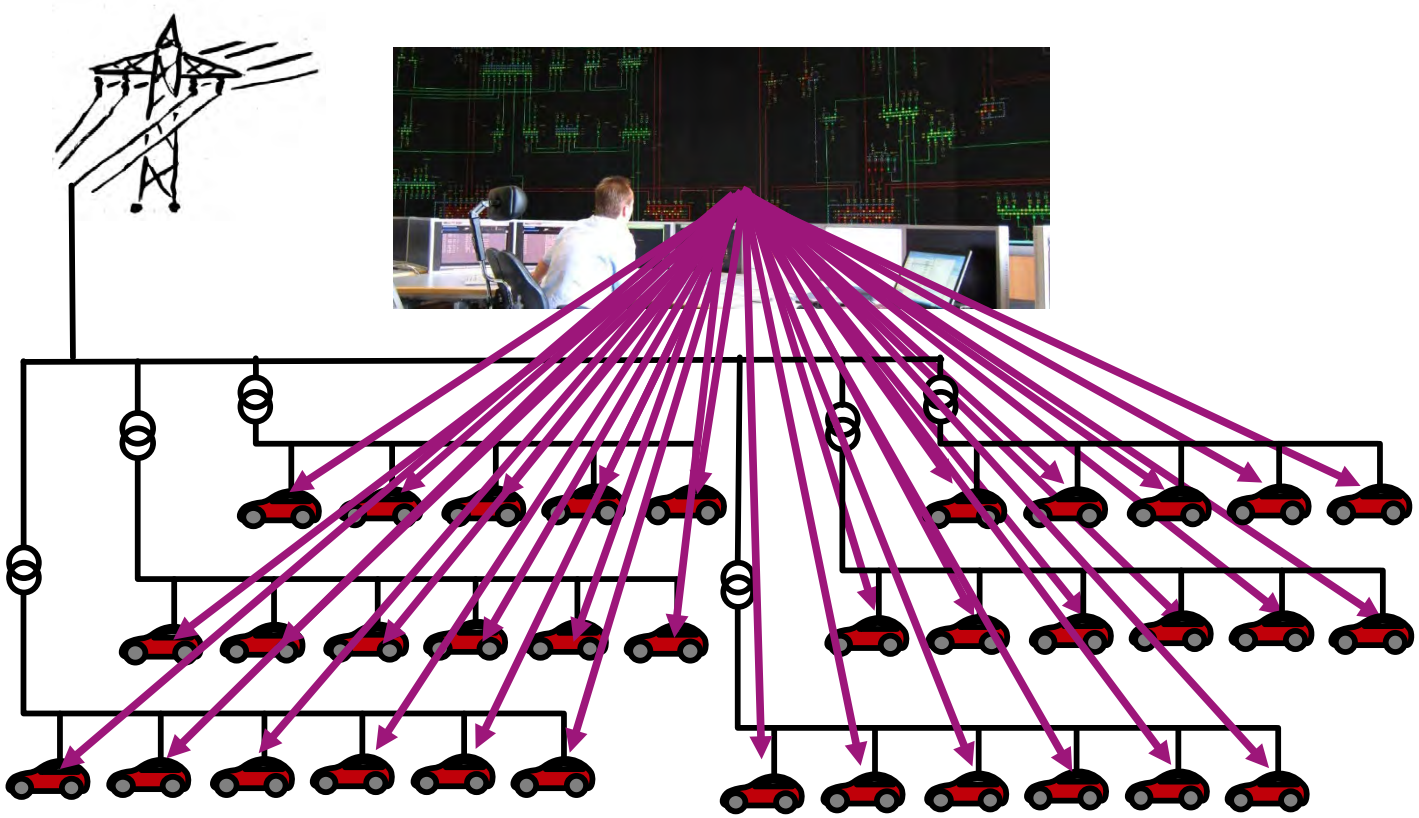
Distributed arrival



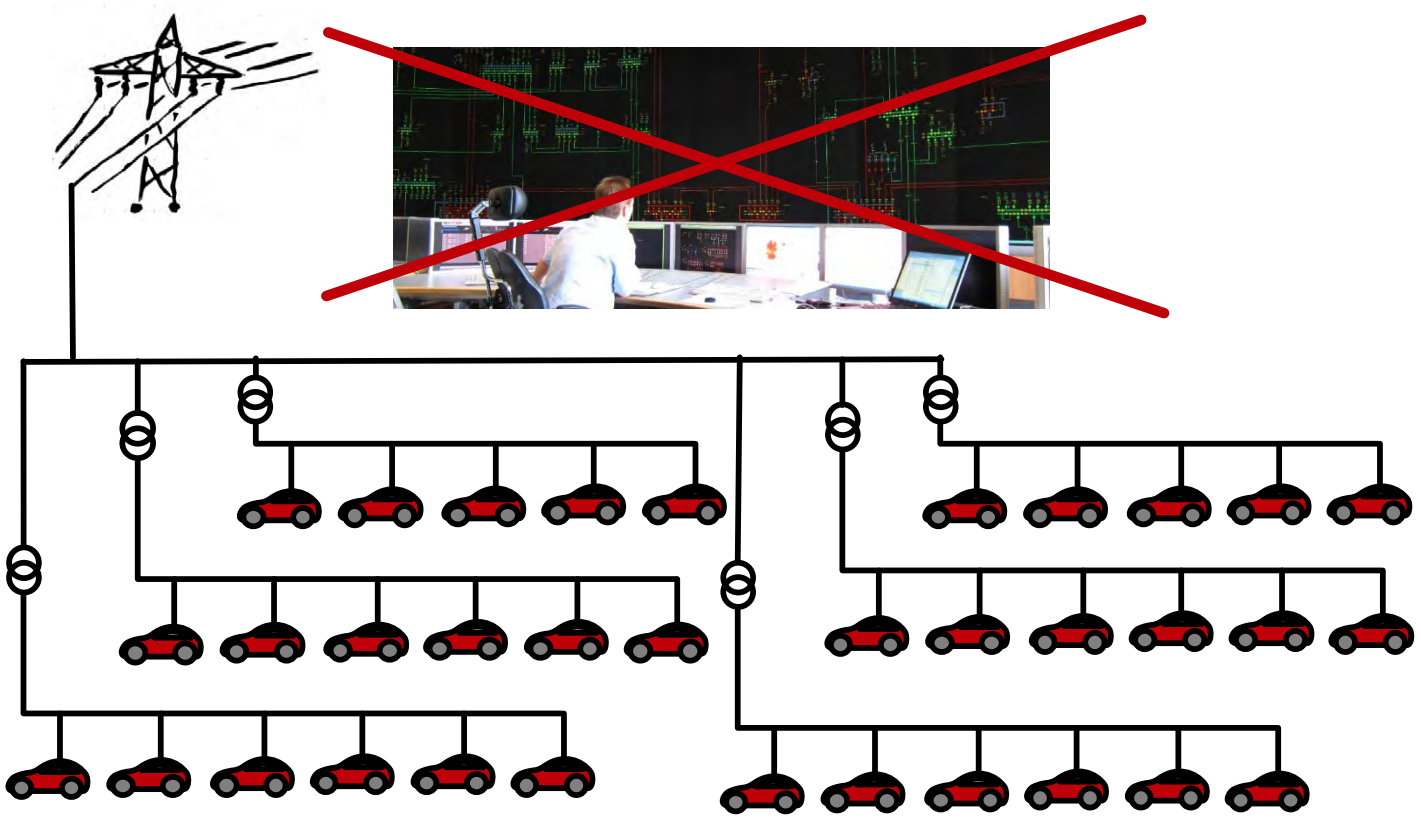
Central Control



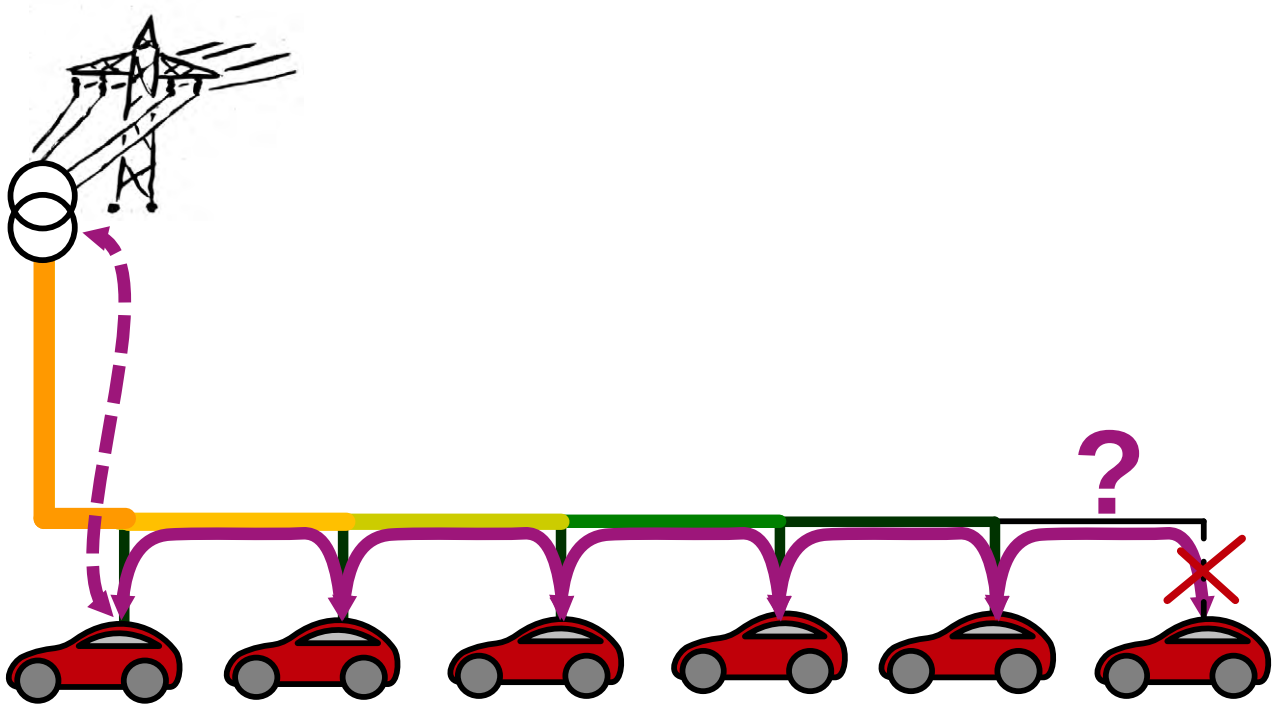
Central Control



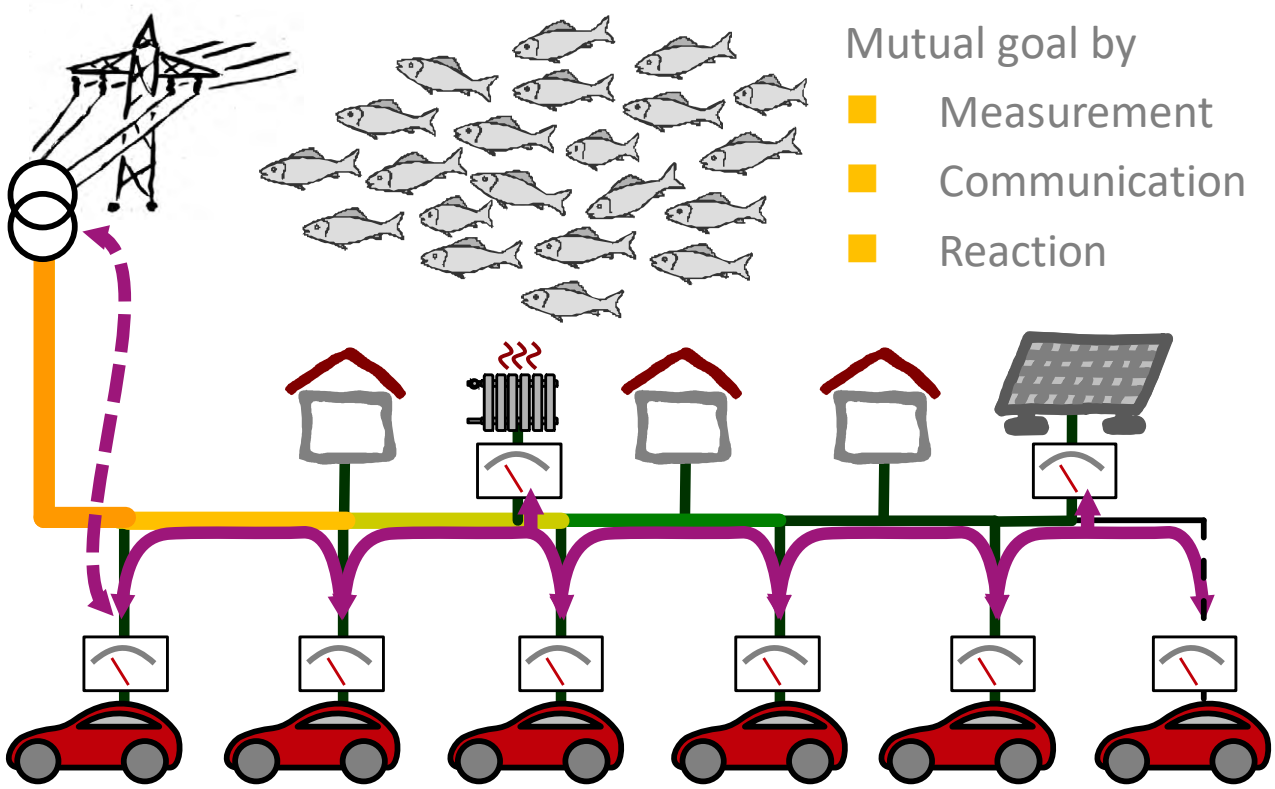
Decentral control



Decentral control

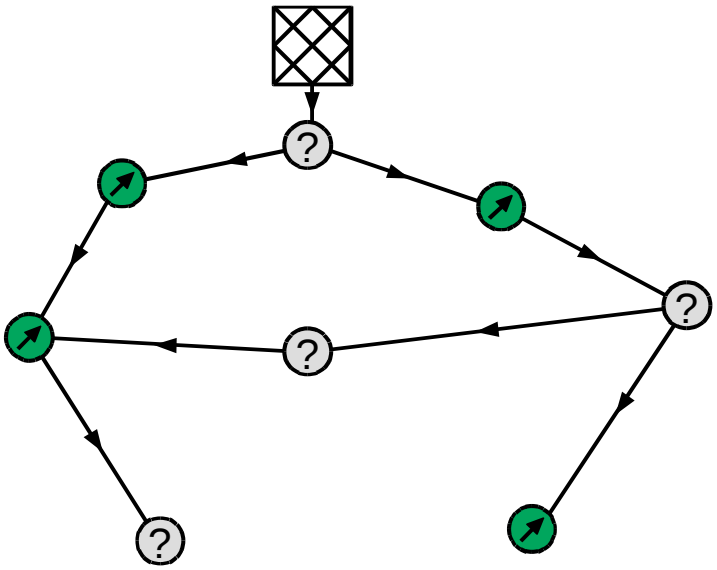


Swarm principle



Grid state estimation

Known nodes n = m unknown nodes



Known node current and voltage

Unknown node current and voltage

Solution:

- Setup equation system with admittance matrix:

Coefficients known from line impedances

Known node currents and voltages

$$\begin{pmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{pmatrix} \cdot \begin{pmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \\ U_6 \end{pmatrix}$$

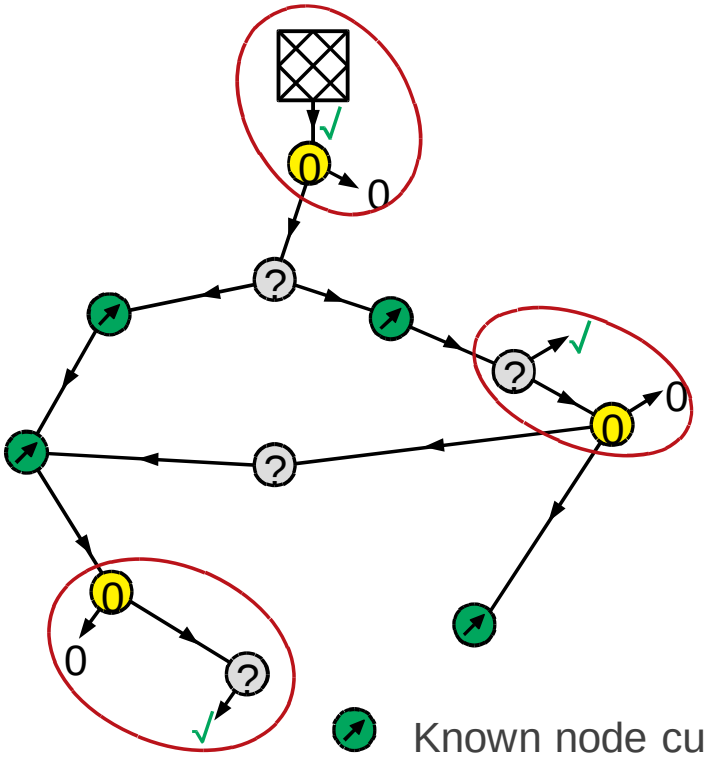
Unknown node currents and voltages

- And solve to unknown

Grid state estimation

Known nodes n < m unknown nodes *or*

Ambiguous arrangements

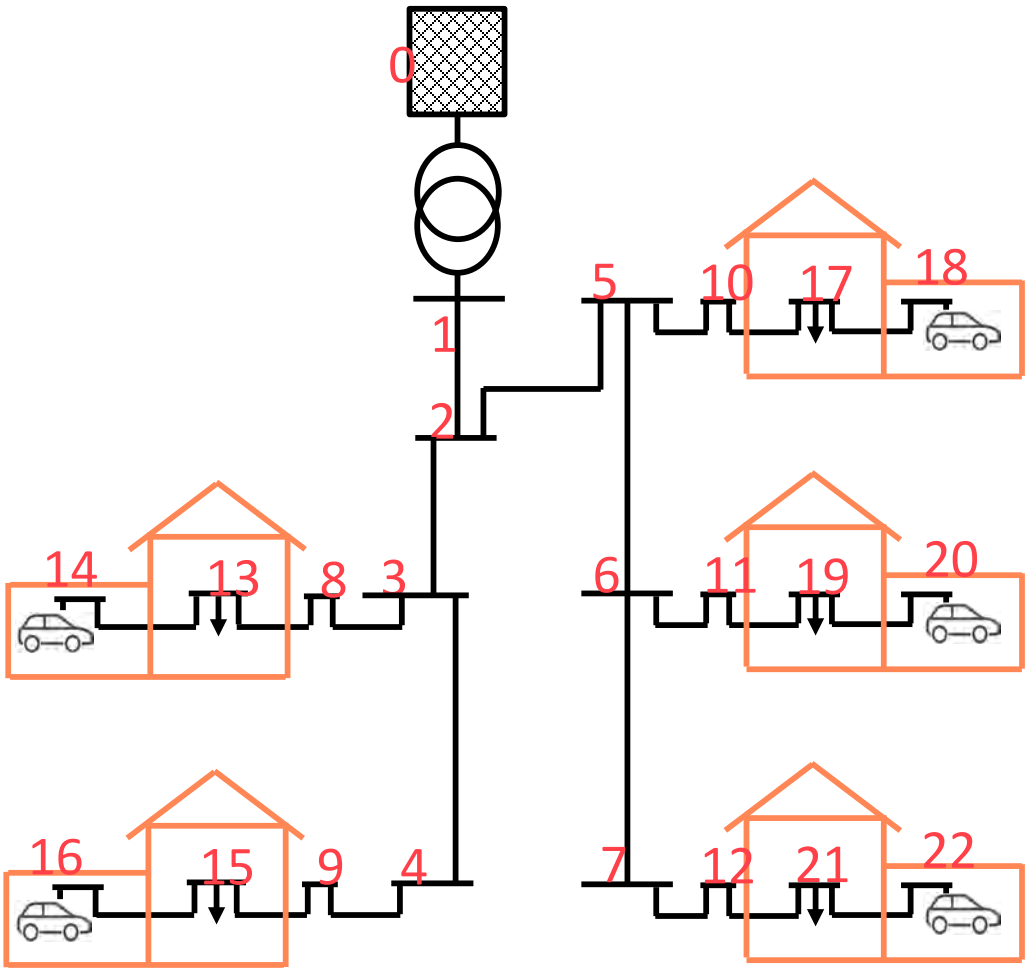


Solution:

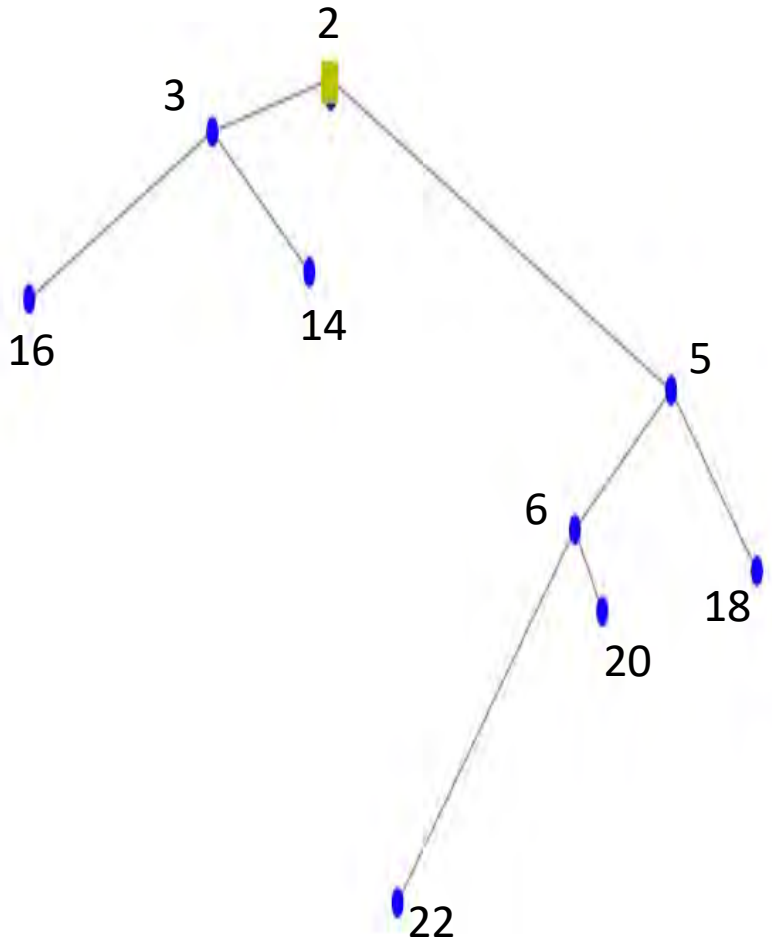
- Select (m – n) nodes and assume a node current
- For worst case:
  - Select nodes, which are *not* at the end
  - Assume node current = 0
  - If ambiguous, calculate all cases
- Each Zero Current Node adds one variable to the equation system
- Equation system is solvable

Grid topology estimation

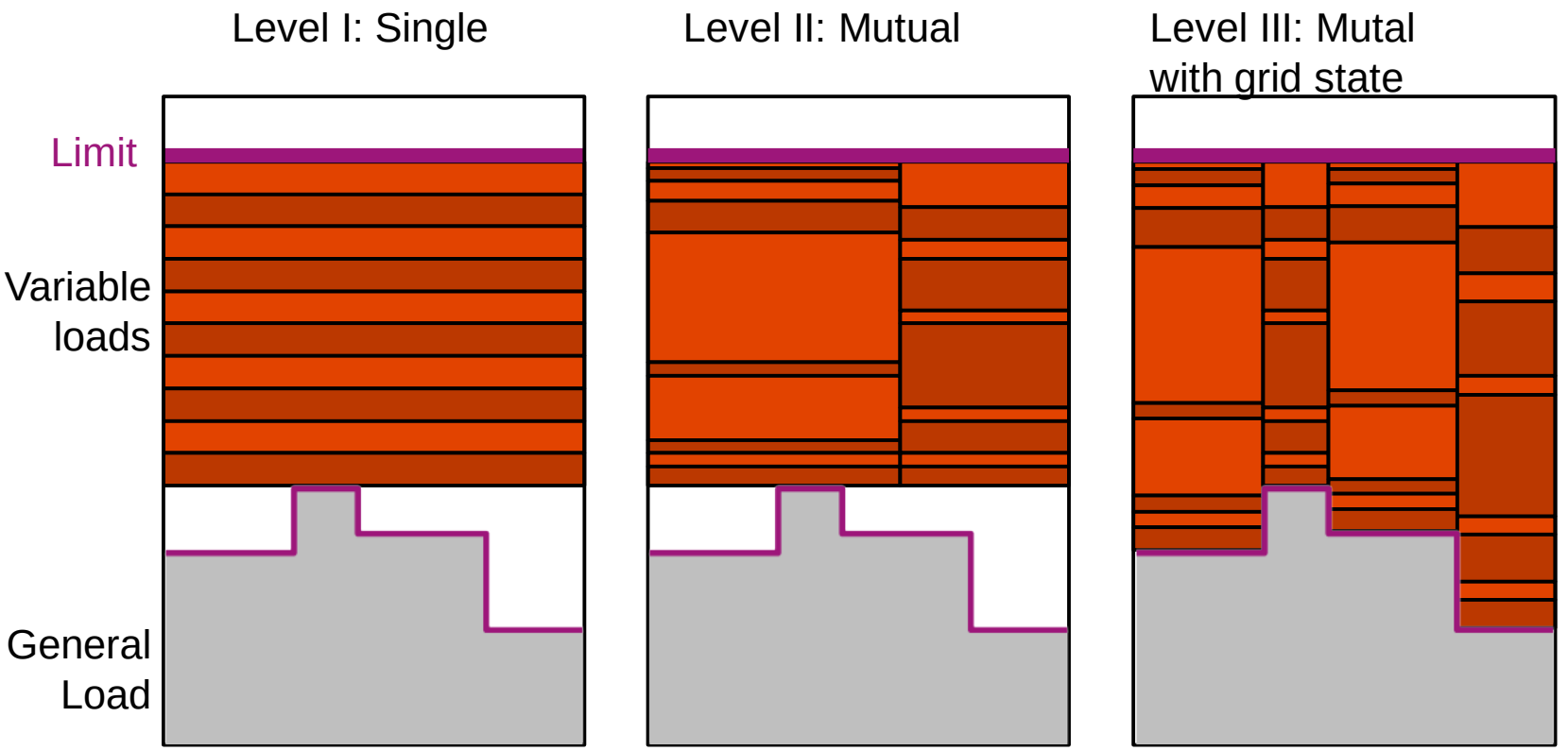
Original power grid



Determined grid topoplogy



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

Distributed arrival

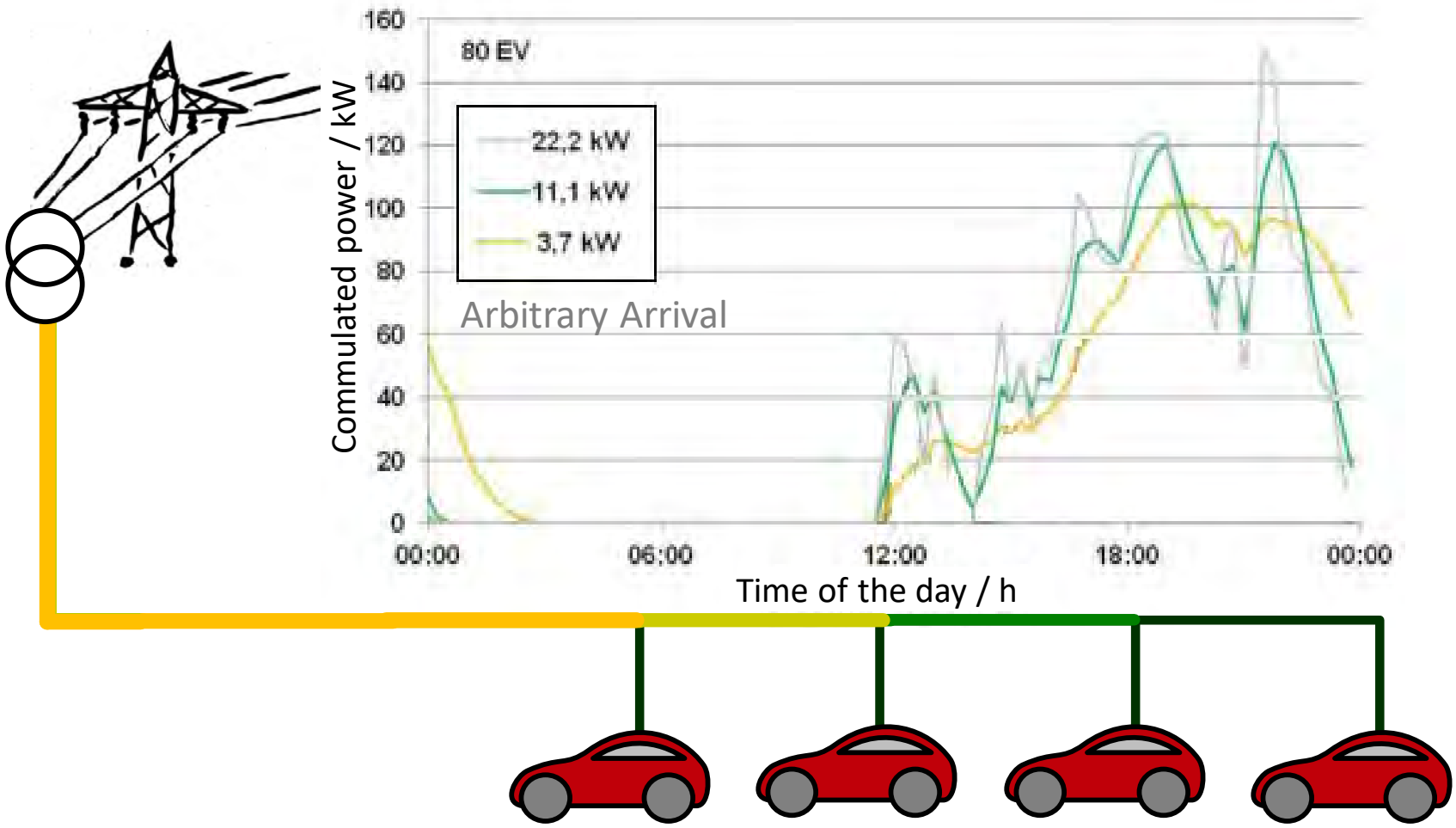


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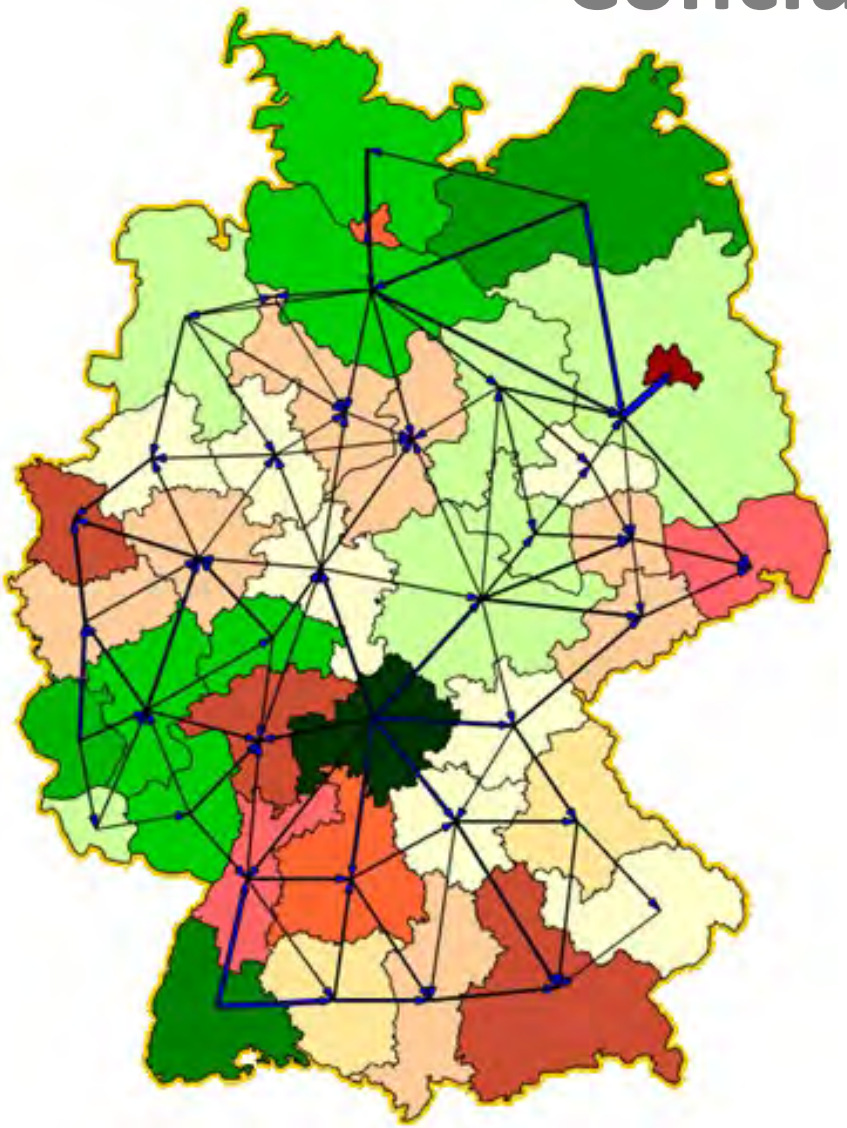
Diagram: T. Doum et al. TH-Köln 2017, http://www.100pro-erneuerbare.com/netze/publikationen/2015-06-Doum/Doum-Lastmanagement_Elektromobilitaet.htm.

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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