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Planning and operation methods for smart distribution grids

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Energy Economics	Transmission- & Distribution Grids	Measurement- & Automation-Systems	Energy Efficiency & Renewable Energy	Center of Excellence E-Mobility

Quelle: TU Dortmund

3 Professors:

- Rehtanz
- Myrzik
- Handschin (em.)

2 Lecturers:

- Dr. Jendernalik
- Dr. Möhl

Staff:

- around 50 scientists
- 4 technical staff

Bachelor and Master students

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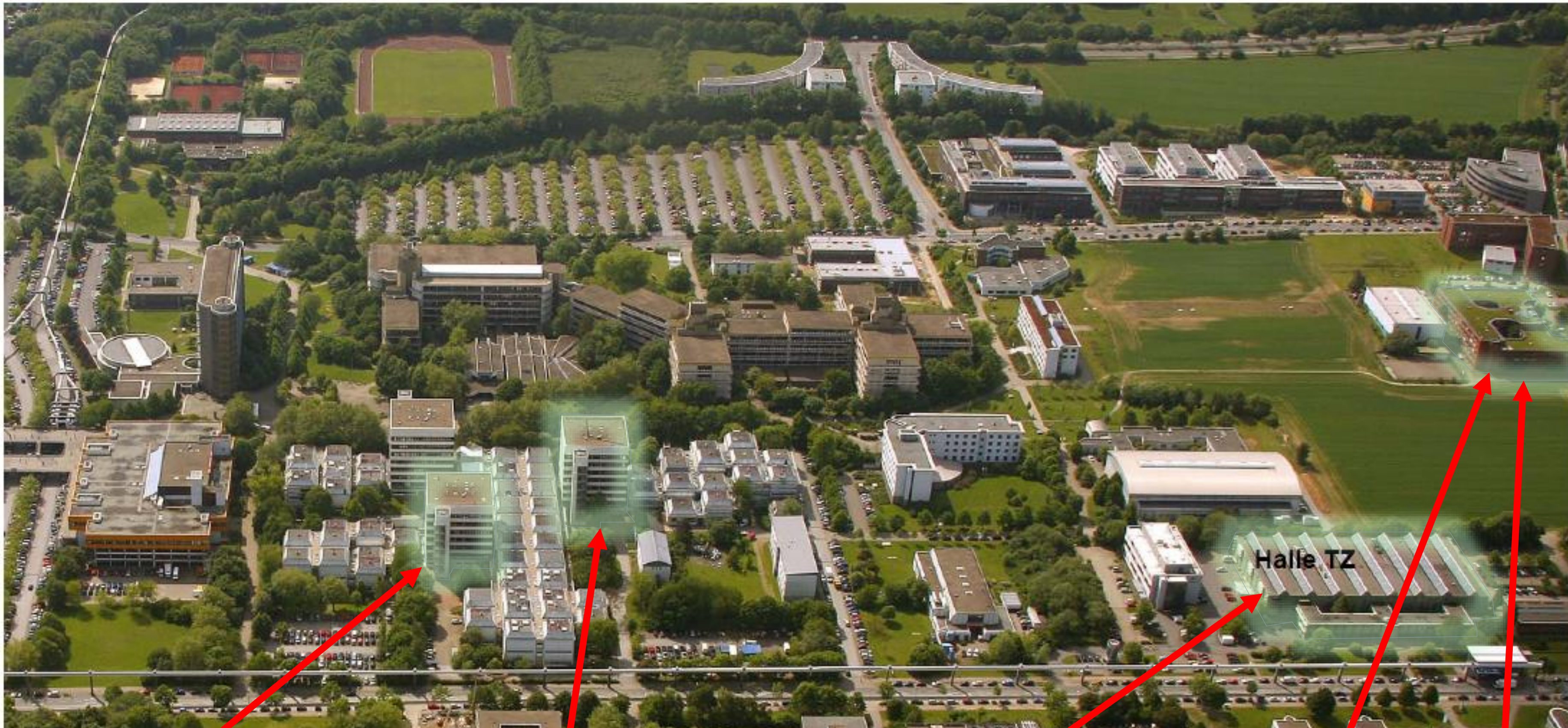

Energy Efficiency & Renewable Energy

Energy Economics & Measurement and Automation Systems

Center of Excellence E-Mobility

NRW Kompetenzzentrum Elektromobilität
Infrastruktur und Netze

Transmission- and Distribution Grids

ef RUHR
DIE ENERGIEDENKFABRIK

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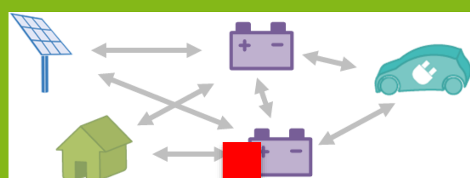
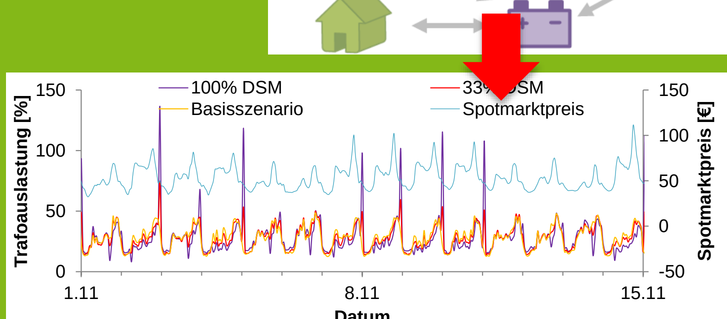
Smart Grids and Smart Markes have to be considered conjointly in planning and operation

Planning

- interaction of innovative netzwork components and market mechanisms
- based on time series





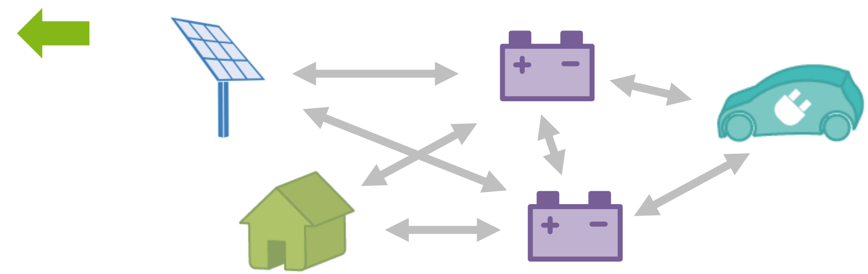
Operation

- coordination of congestions and market curtailment
- network state estimation
  - sparse measurements
  - robust against errors
  - adaptive to network situations

Time-Series based distribution grid planning with

AGENT-BASED SYSTEM

Distribution grid planning with agent-based system

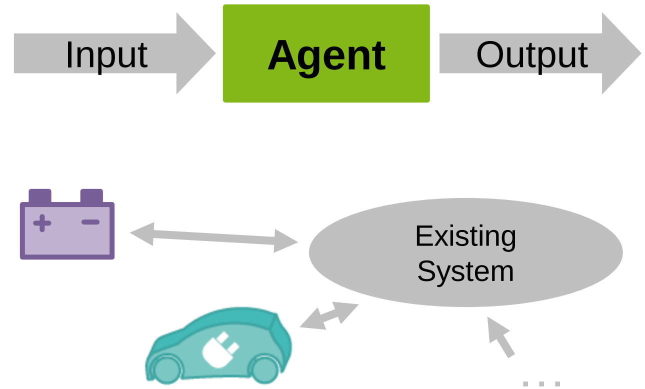


Today:
Dimensioning with estimated extreme values

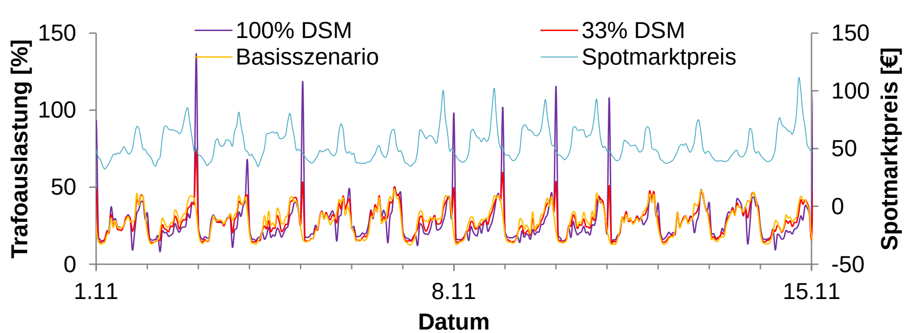
Tomorrow:
- Time series based planning
- Consideration of DSM, storage, innovative devices, etc.

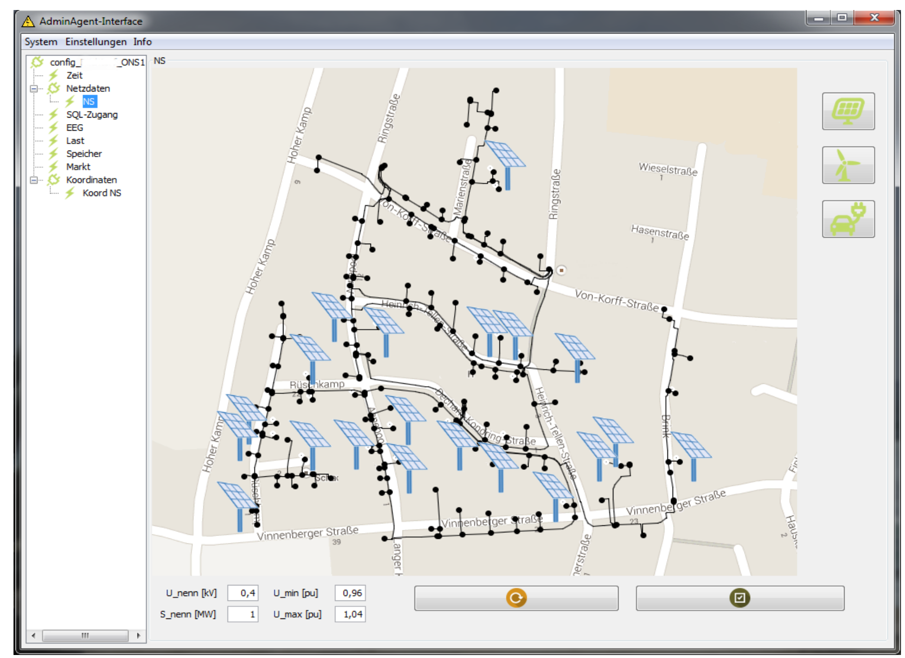
- **Target:**
  Simulation environment for easy generation of time series and integration of innovative devices and methods

The agent-based system



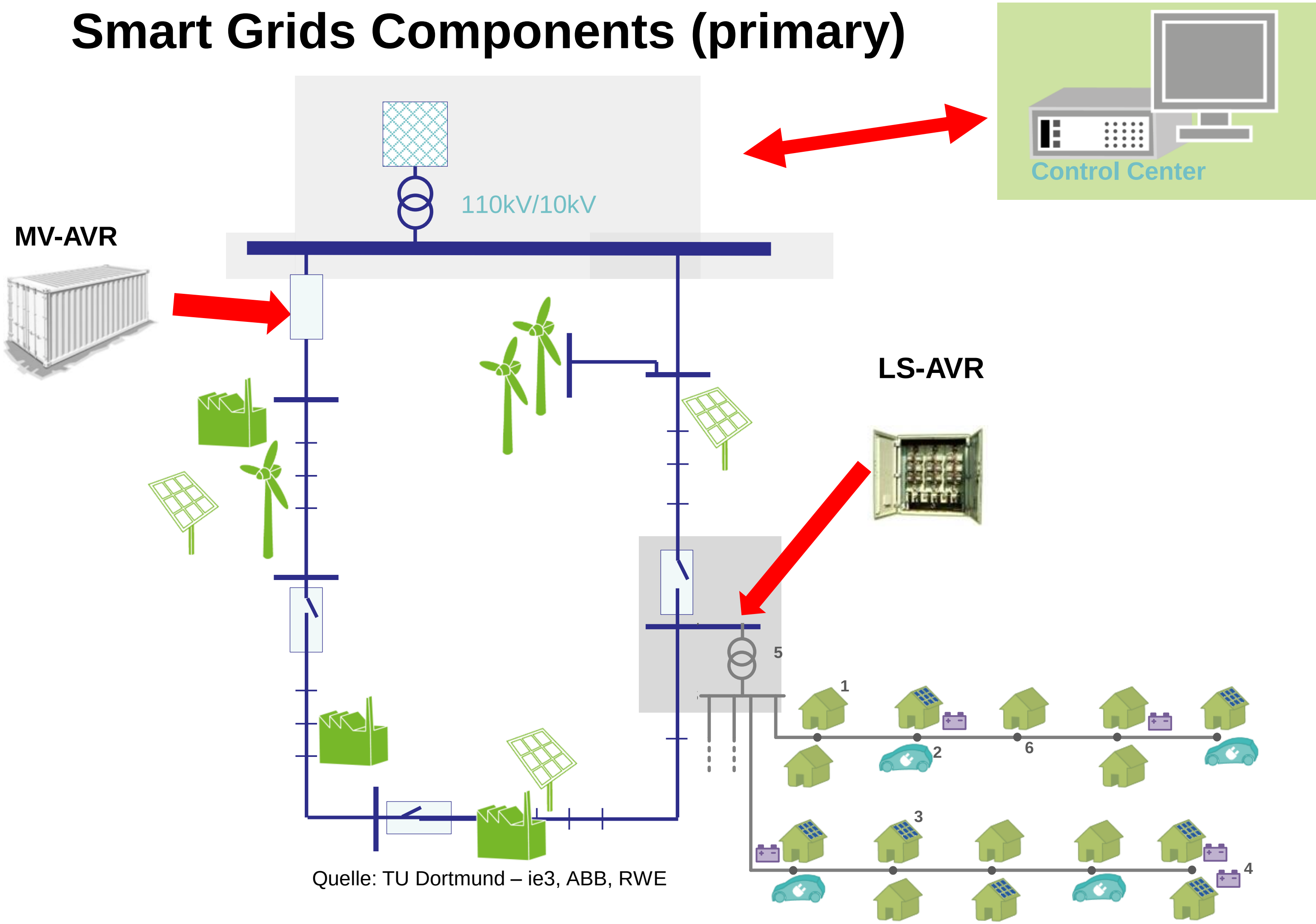
- Segmentation of complex interactions
- differentiated degrees of details
- Flexible expansion
- Consideration of individual behaviour and negotiation





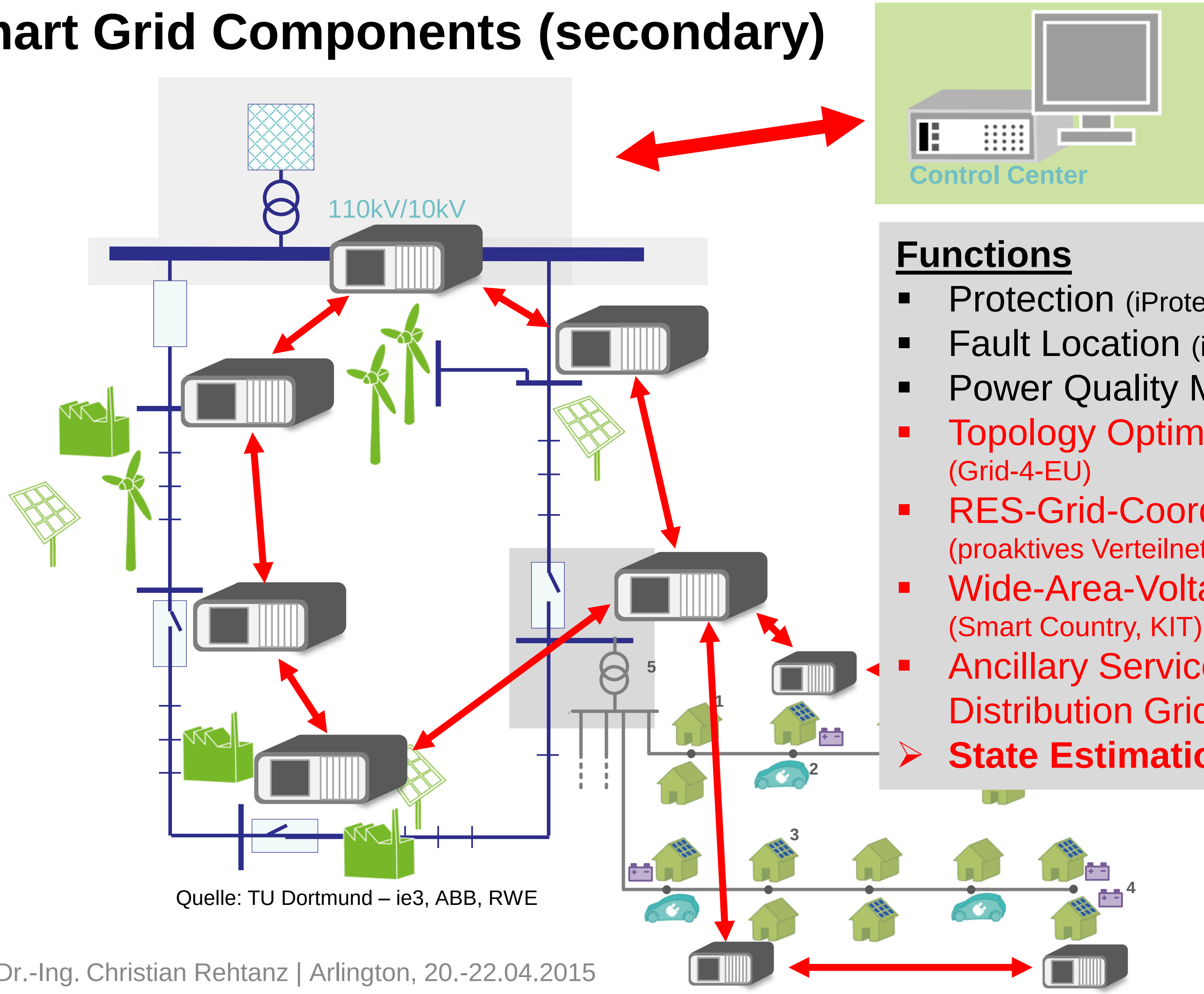
Quelle: TU Dortmund – ie3

Smart Grids Components (primary)



Quelle: TU Dortmund – ie3, ABB, RWE

Smart Grid Components (secondary)



Functions

- Protection (iProtect)
- Fault Location (i3S)
- Power Quality Monitoring
- Topology Optimization (MS) (Grid-4-EU)
- RES-Grid-Coordination (proaktives Verteilnetz)
- Wide-Area-Voltage-Control (Smart Country, KIT)
- Ancillary Services from Distribution Grid (KIT)
- ➢ **State Estimation**

Quelle: TU Dortmund – ie3, ABB, RWE

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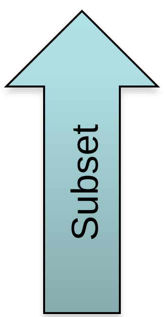
Operation of Smart Grids with

ADAPTIVE STATE ESTIMATION (ASE)

The Estimation Problem

Input data
(unknown)

$$\mathbf{m} = \begin{bmatrix} m_1 \\ \vdots \\ m_\mathrm{m} \end{bmatrix}$$



Potential measurements

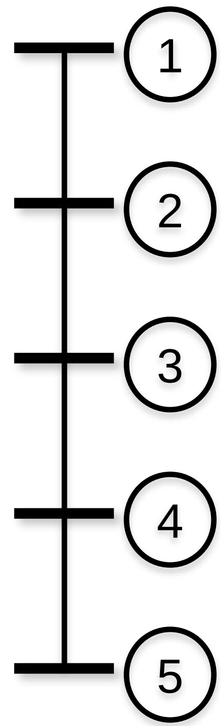
$\lvert V_1 \rvert$	δ_1	P_1	Q_1	$\lvert i_1 \rvert$
$\lvert V_2 \rvert$	δ_2	P_2	Q_2	$\lvert i_2 \rvert$
$\lvert V_3 \rvert$	δ_3	P_3	Q_3	$\lvert i_3 \rvert$
$\lvert V_4 \rvert$	δ_4	P_4	Q_4	$\lvert i_4 \rvert$
$\lvert V_5 \rvert$	δ_5	P_5	Q_5	$\lvert i_5 \rvert$

System-
equations

$$\mathbf{m}(\mathbf{v}) = \begin{bmatrix} m_1(\mathbf{v}) \\ \vdots \\ m_\mathrm{m}(\mathbf{v}) \end{bmatrix}$$

No
inverse

Network model
(known)



Internal state
(unknown)

$\lvert V_1 \rvert$	δ_1
$\lvert V_2 \rvert$	δ_2
$\lvert V_3 \rvert$	δ_3
$\lvert V_4 \rvert$	δ_4
$\lvert V_5 \rvert$	δ_5

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Adaptive State Estimation determines the model coverage for number, distribution and kind of input data

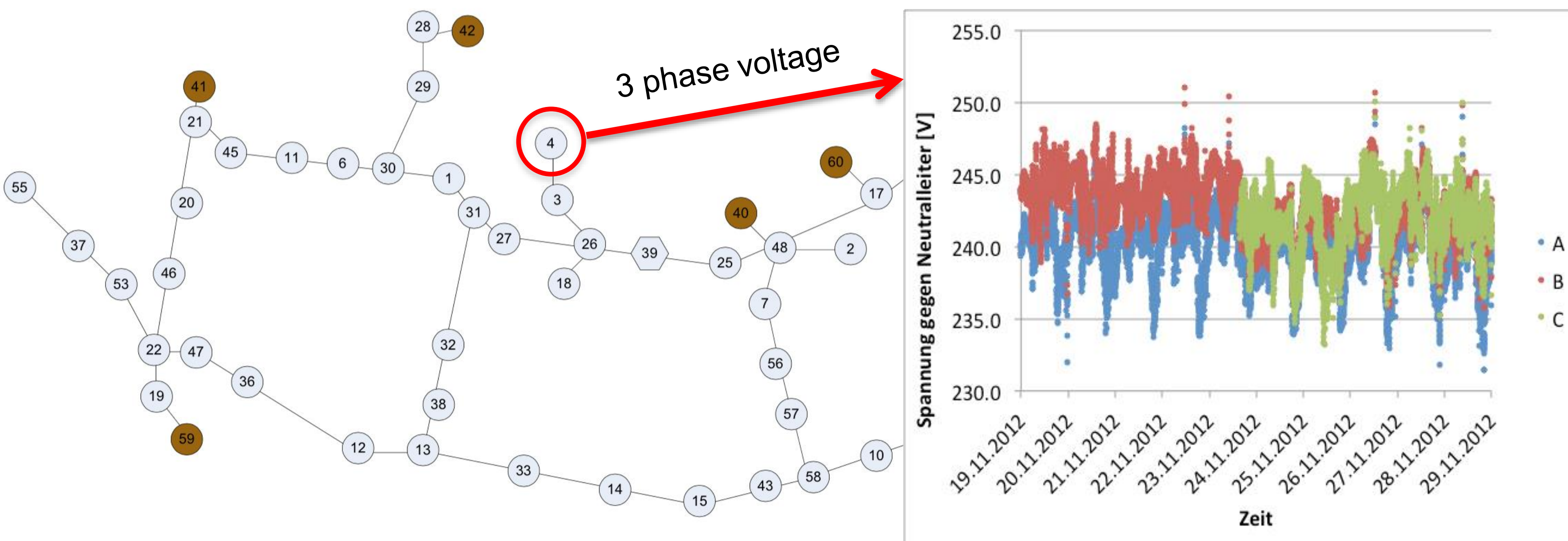
- **overdeterminded -> classical State Estimation**
  - Redundant measurement data, all state variables can be determined
- **exact determination -> power flow calculation**
  - Non-redundant measurement data, all state variables can be determined
- **Underdetermined / mixed determined -> Adaptive State Estimation**
  - Non-redundant measurment data, not all state variables can be determined
  - States of (partially) observable islands are solved simultaneously within one interconnected grid model
  - Solves partially underdetermined systems

Comparison of classical SE, power flow and Adaptive SE

- **All three methods use similar iteration process**, in which a linearisation of the system equations (Jacobian-Matrix) is inverted to improve the estimated states.
- For **exactly determined problems** the Jacobian-Matrix is regular and can be inverted (see Newton-Raphson-Power Flow).
- For **under- and overdetermined problems** the Jacobian-Matrix is singular and does not have an inverse. Both the classical and the presented Adaptive SE use the Moore-Penrose-Inverse (called ‚Pseudo-Inverse‘). But:
  - **Classical SE** can not determine the Pseudo-Inverse for underdetermined problems.
  - ➢ **Adaptive SE** uses for the calculation of the Pseudo-Inverse the singular value decomposition and can solve underdetermined problems.

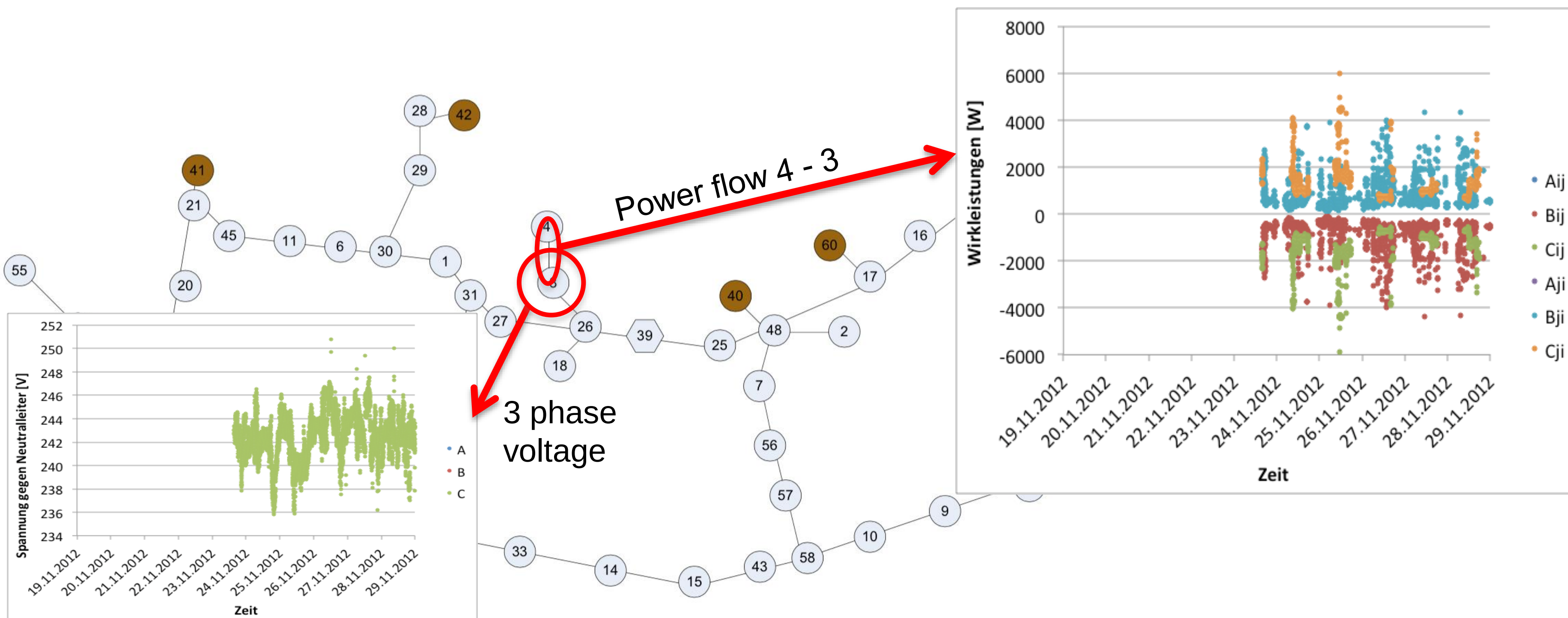
ASE: no requirements for kind, number and distribution of measurement data

- Usage especially in MV- and LV-grids with sparse measurment coverage
- Example: LV-distribution grid (3 phase + neutral) with Smart Meter Measurements collected via PLC



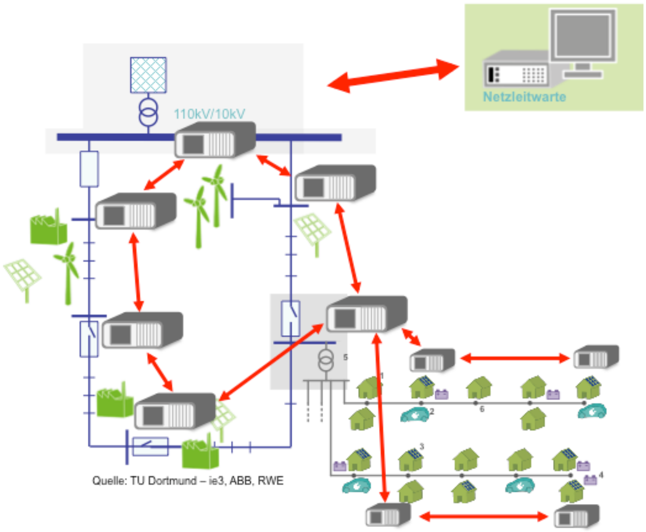
ASE: no requirements for kind, number and distribution of measurement data

- Example: Bus 2 partly not observable. Power Flow bus 4 to bus 3 can be determined.



ASE - Conclusions

- **High flexibility and robustness**
  - for sparse / changing measurement data
  - for sparse observability and underdetermined systems or network islands



- **Additional Options**
  - Determineation of minimal measurement configutations
  - Optimal control through load/DG-management possible
  - Estimation of model parameters (grid components) from overdetermined measurement data

IMPLEMENTATION OF SMART-GRID-FUNCTIONS

EU-Project Grid-4-EU

Implementation by
RWE, ABB, TU Dortmund in Reken

Bildquelle: TU Dortmund

Standard-ICT and industrial automation for control and protection

Quelle: TU Dortmund

Quelle: Beckhoff Automation

THANK YOU VERY MUCH FOR YOUR ATTENTION!