IFHT Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

Grid integration of electric vehicle fleets using a traffic light concept

Maria Vasconcelos, M.Sc.
Marcel Kurth, M.Sc.
Prof. Dr.-Ing. Armin Schnettler

Agenda

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

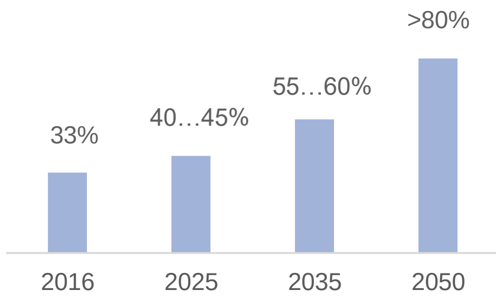
- Introduction
- Smart grid traffic light concept
- Simulation framework
- Exemplary results
- Conclusion

Introduction

Challenges at distribution level

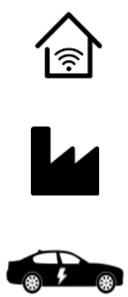
Renewable Energy Sources (RES)

Goal of the German Renewable Energy Law (EEG)



Electrification of mobility and heat sector

Increasing electric load



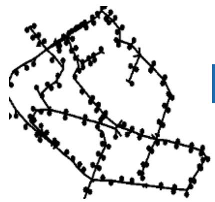
Expected flexibility potential of smart home devices 2020:
- 17,4 GW (winter)
- 16,6 GW (summer)

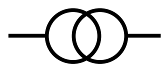
Expected potential of industrial processes 2020:
- 4,5 GW

Expected flexibility potential of electric vehicles 2020:
- 2 GW

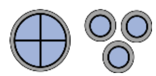
1)

Bottlenecks in distribution grids





Transformer overloading



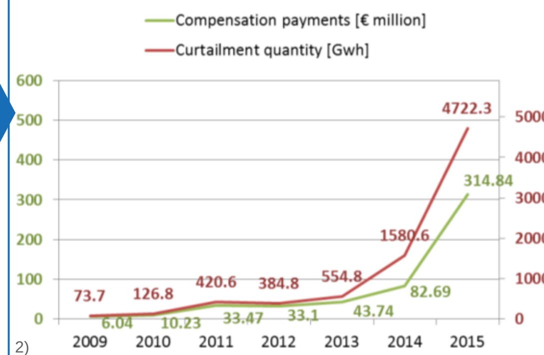
Line overloading

V

Voltage violations

Feed-in management

- Curtailment of RES by DSO (§ 14 EEG)



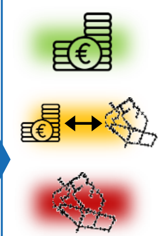
2)

Demand side management

- Consumption devices in low voltage grids remote controllable by DSO (§14a EnWG)
- in exchange, a reduced net charge is calculated for these suppliers and final consumers

Need for an **unbundling-compliant, market-based demand and local feed-in coordination** in distribution grids

- Alternative to grid reinforcement and expansion measures
- Possible solution: smart grid traffic light concept and grid-oriented flexibility market



Market phase

Interaction phase

Grid phase

[1)]VDE, 2012: *Demand Side Integration;* [2)]Bundenetzagentur, 2016: *Monitoring report 2016*

Introduction

Goal and scope

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

Considering different frameworks

Legal regulatory framework	*Identification of necessary adjustments of legal regulatory framework*
Institutional framework	*Definition of roles and interactions for the actors involved in the exchange of grid-oriented flexibility*
Technical framework	*Technical requirements and restrictions for the provision of grid-oriented flexibility and grid operation*

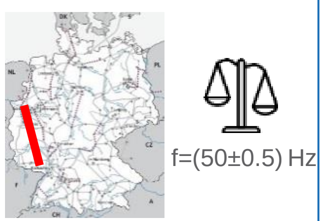
Considering concurring flexibility options

Market-oriented flexibility

Contribution to profit maximization

System-oriented flexibility

Contribution to system-wide stability measures

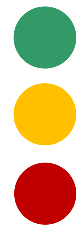


Grid-oriented flexibility

Contribution to local grid control measures

Development of a simulation framework for a smart grid traffic light concept

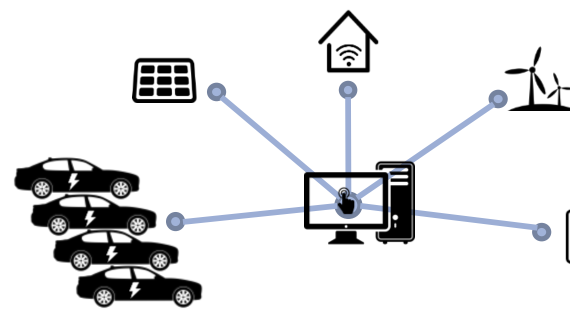
Development of smart grid traffic light configurations



- Considering uncertainties
- Definition of Thresholds

$(S_{transformer}, S_{line}, V_{min}, V_{max})$

Assessment of electric vehicle fleets' potential to provide grid-oriented flexibility for different scenarios



Agenda

Introduction

▶ Smart grid traffic light concept

Simulation framework

Exemplary results

Conclusion

Smart grid traffic light concept

Configuration proposal

Phase 1 – planning & trading without grid restrictions

- Aggregator (e.g. owner of an EV fleet) manages its DER network taking individual constrains forecasts into account (e.g. mobility demand and waiting times of EVs)
- Trader (e.g. Virtual Power Plant – VPP) optimizes DER schedules at day-ahead and control power market and forwards them to DSO

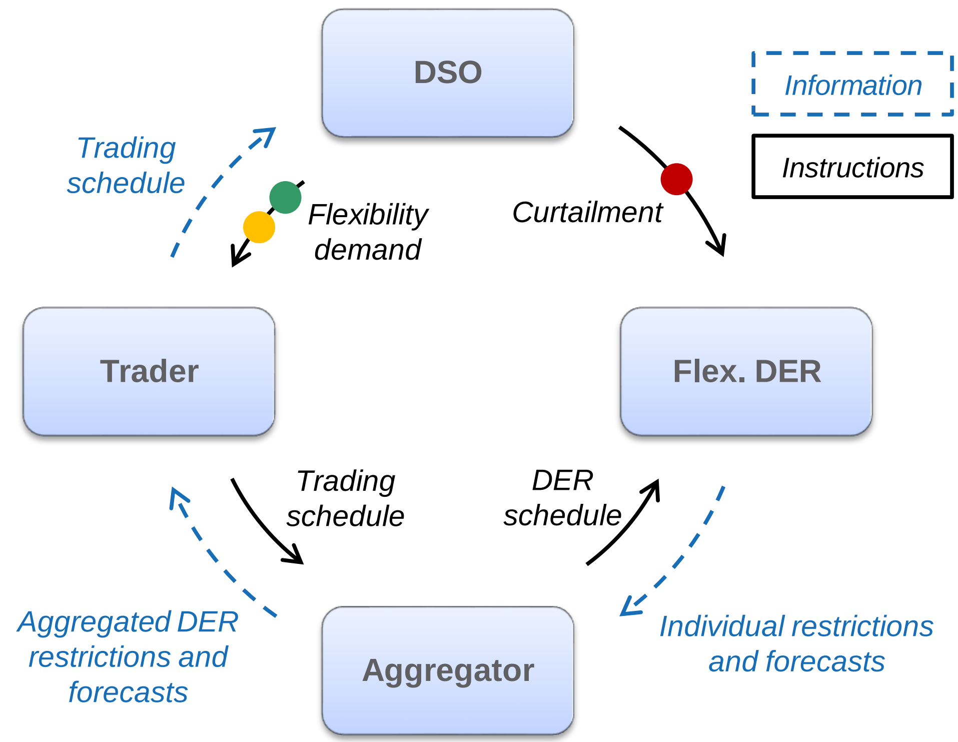
Phase 2 – grid state forecast & procurement of grid-oriented flexibility

- Case 1: no flexibility procurement by DSO when no bottlenecks expected (green phase)
- Case 2: time- and location-specific flexibility procurement by DSO when bottlenecks expected (amber phase); trader carries out a new scheduling optimization on the spot-market considering grid constrains and forwards a new aggregated schedule to aggregator

Phase 3 – real time operation

- Aggregator carries out a breakdown into individual DER-schedules
- In case of bottlenecks, the DSO curtails individual DER via remote control (red phase)

TLC configuration proposal



Smart grid traffic light concept

Considering different frameworks

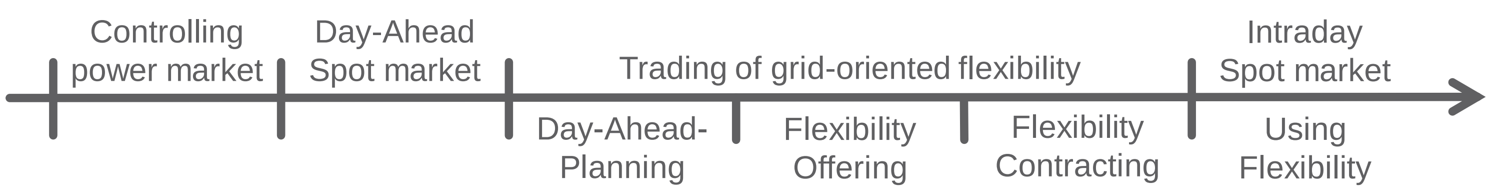
Legal regulatory framework

Competitive actors can fulfill their schedules; system operators can take grid-oriented measures if need be	§ 13 Par.1 Nr. 1 EnWG
System operators fall back to market-oriented measures (e.g. balancing power)	§ 13 Par.1 Nr. 3 EnWG
System operators fall back to ultima ratio measures (e.g. feed in management)	§ 13 Par. 2 EnWG; § 14 EEG

Creation of incentives for flexibility offer: Abolition of financial compensations for feed-in management

Creation of incentives for flexibility demand: levy of financial compensations for feed-in management measures on network share must be abolished

Institutional framework



Technical framework

Increasing share of intelligent Measurement Systems (iMSys) – measurement of voltage value and/or apparent power

- Loads > 6,000 kWh/year
- Distributed generators > 7 kW
- Remote controllable loads

⇨ DSO gets sufficient information about grid state to identify bottlenecks

Agenda

Introduction

Smart grid traffic light concept

Simulation framework

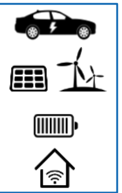
Exemplary results

Conclusion

Simulation framework
Overview

Input

DER portfolio



Grid topology

Operational targets
- Self-consumption optimization
- Active in spot markets
- Active in balancing power market

Traffic light parameters
- Thresholds
- Flexibility product requirements

Simulation framework

market

planning & trading without grid restrictions

grid

grid state forecast

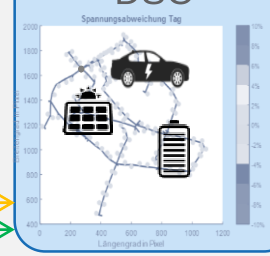
Forwarding schedules

DER

Aggregator

Trader

DSO



procurement of grid-oriented flexibility

Output

- Flexibility requirement
- Flexibiliy cost
- Effectiveness
- Efficiency

Simulation framework

Overview

Market

Operational scheduling process

DER

Aggregator

Trader

Generation forecasts

Price forecasts

Operational targets

Electric vehicle fleet:
- Driving profiles
- Vehicles' S.O.C. at arrival
- Vehicles' target S.O.C.
- Charging energy
- Uni- vs. bidirectional charging
- Capacity restrictions
- Power restrictions

$$\max c * \vec{x}$$

Scenario n

Scenario 2

Scenario 1

DER constraints

Market constraints

eeX

EPEX

DER & market coupling constraints

...

Stochastic coupling constraints

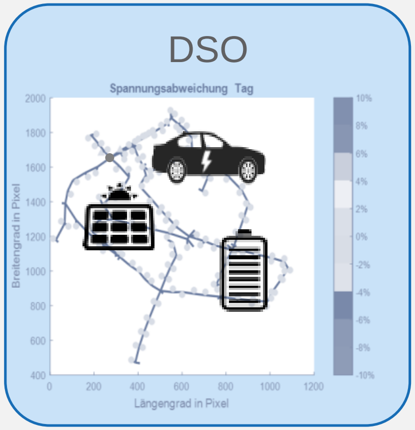
- Day-ahead operational scheduling process
- Stochastic optimization model (MILP): profit maximization restricted by technical and market constraints
- Electric vehicle fleet‘s restrictions determined in a preliminary simulation

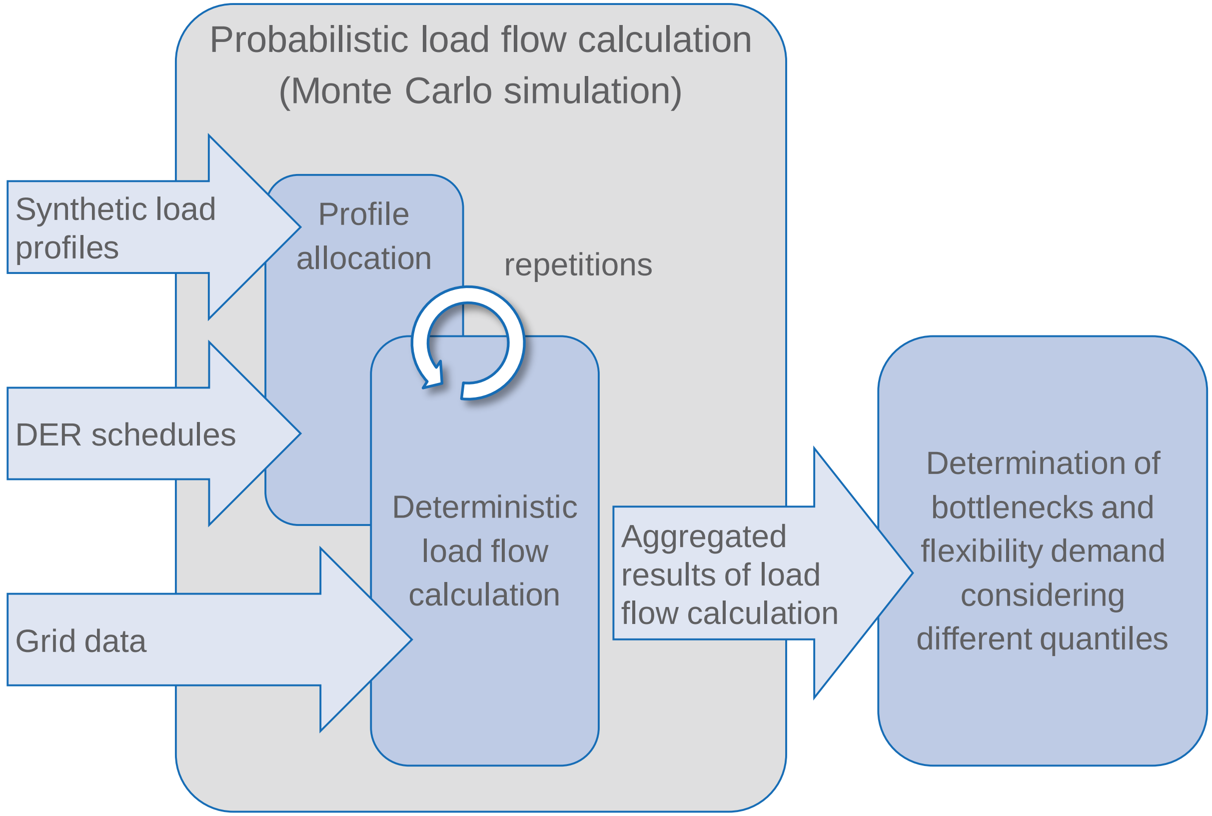
Simulation framework

Overview

Grid

Grid state forecast





Agenda

Introduction

Smart grid traffic light concept

Simulation framework

▶ Exemplary results

Conclusion

Exemplary results

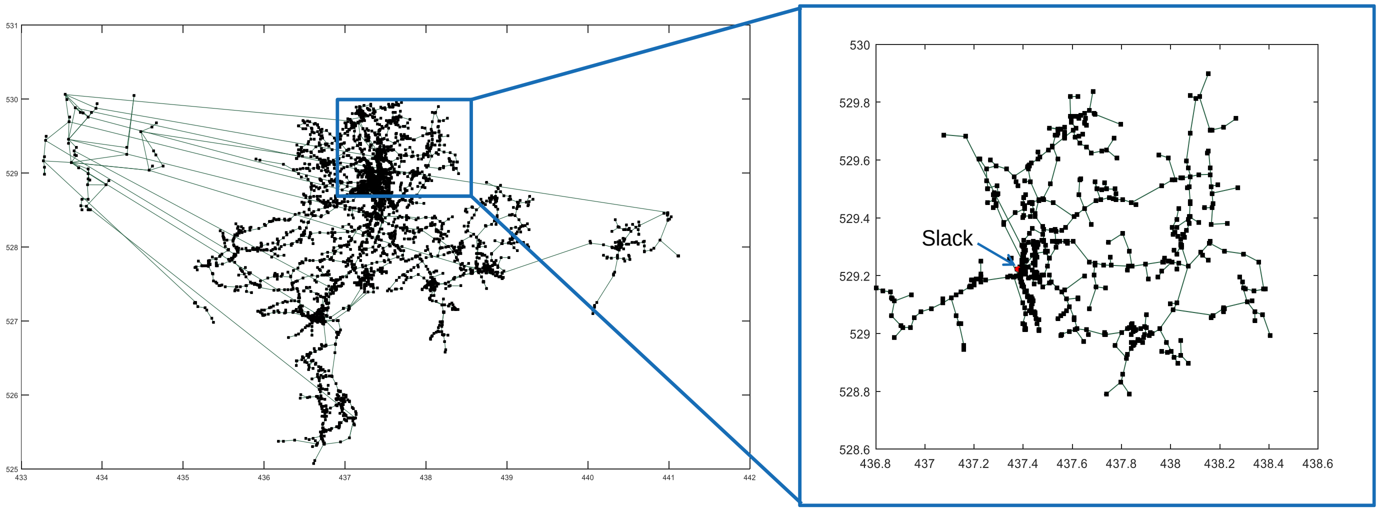
Use case

DER of the Virtual Power Plant

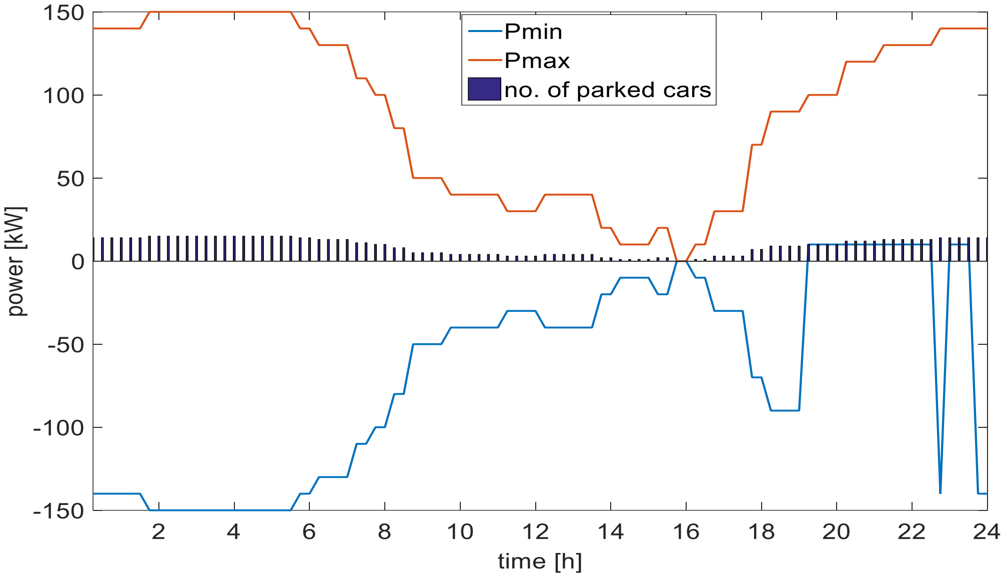
DER	Total installed power
Photovoltaic units (PV)	394 kW
Wind energy units (WEU)	2,000 kW
Combined heat and power units (CHP)	1,718 kW
Storage units	300 kW (360 kWh)
Load bank	150 kW
Genset	80 kW
Electric vehicle fleet	15 vehicles; 100 kW each (50 kWh)

- Use case
  - Medium voltage grid
  - Loads, uncontrollable DER, a virtual power plant
- Exemplary day in August
  - Daily feed-in amounted to 280 MWh
  - Daily demand amounted to 720 MWh

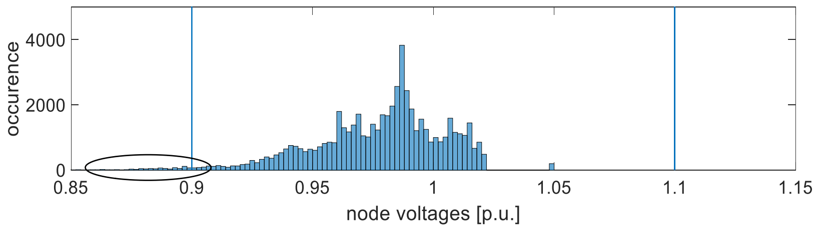
Medium voltage grid



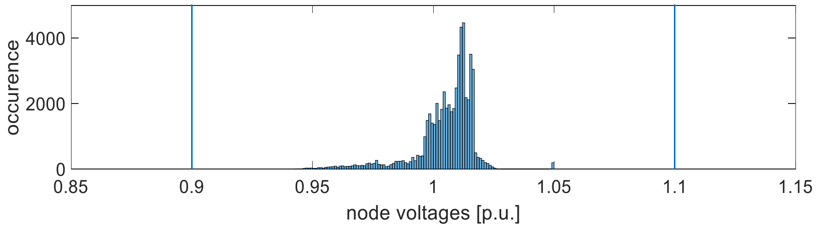
Flexibility range of the electric vehicle fleet



Node voltages without flexibility



Node voltages with grid-oriented flexibility



- DS identifies/forecasts voltage violations (amber phase)
- Grid-oriented flexibility provision technically feasible, only dependent on economic considerations (i.e. opportunity costs of VPP, unit-specific curtailment costs)

- Grid-oriented flexibility provision:
  - Total: 22 MWh
  - Photovoltaic unit: 85%
  - CHP: 6%
  - EV fleet: 9%

Agenda

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

Introduction

Smart grid traffic light concept

Simulation framework

Exemplary results

▶ Conclusion

Conclusion

- Increasing shares of distributed generation and flexible loads may lead to high loading of distribution grids due to concurrency factors
- Increase of feed-in management measures and need for grid expansion/reinforcement
- Unbundling-compliant solution approaches for distribution grids are needed, which make use of DERs' grid-oriented flexibility
- A specific configuration proposal for the traffic light configuration envisages an increased communication between DER, aggregators, traders and DSO
- Electric vehicle fleets are potential candidates for the provision of grid-oriented flexibility
- Integrating the electric vehicle fleets into virtual power plants can have economic and grid-oriented benefits because of synergies between the different DER

Thank you for your attention

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Authors

Maria Vasconcelos, M.Sc.
vasconcelos@ifht.rwth-aachen.de

Marcel Kurth, M.Sc.

Prof. Dr.-Ing. Armin Schnettler

Marcel Kurth, M.Sc.
RWTH Aachen University
Institut für Hochspannungstechnik

Tel. +49 (0) 241 / 80 93039
kurth@ifht.rwth-aachen.de