OpSim: Test and simulation environment for grid control and aggregation strategies

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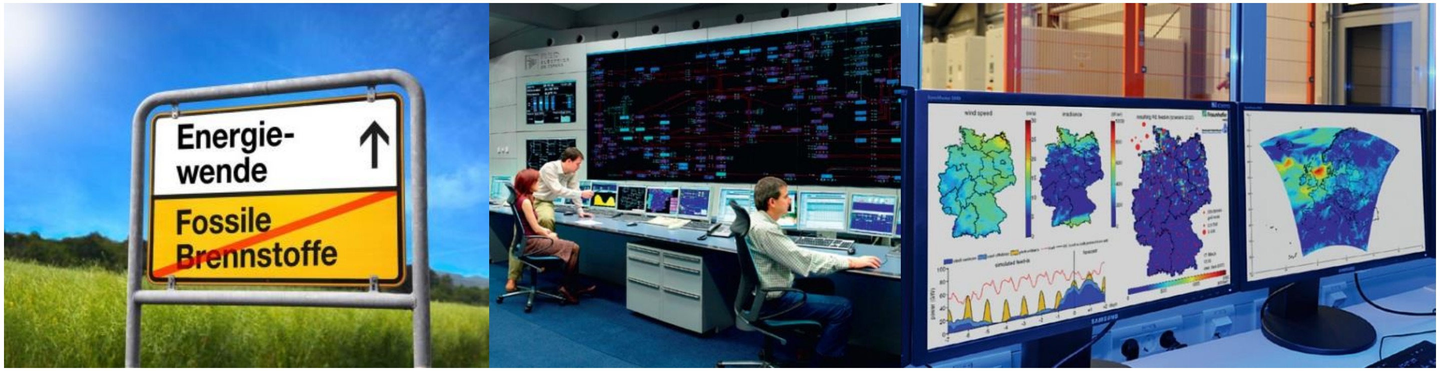

IRED 2018, Vienna

Session 4: Transmission and Distribution Interaction, Systems Integration, Modelling & Simulation

18 October 2018

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Outline

- Motivation (German perspective)
- **New operational strategies: TSO-DSO-DSO-interaction**
  - Provision of ancillary services by controllable distributed energy units
  - Reactive power coordination and congestion management
  - Cascaded control
  - Example projects: SysDL2.0, EU-Sysflex, SINTEG c/sells, IMMOWEN
- **Co-simulation with OpSim**
  - Architecture
  - Testing with OpSim
  - OpSim as a service

Energy System Transformation (Today – Future – Megatrends)

Decarbonisation

> 35% RES in electrical energy

Some regions >100%

2050: 80-100% RES in all sectors

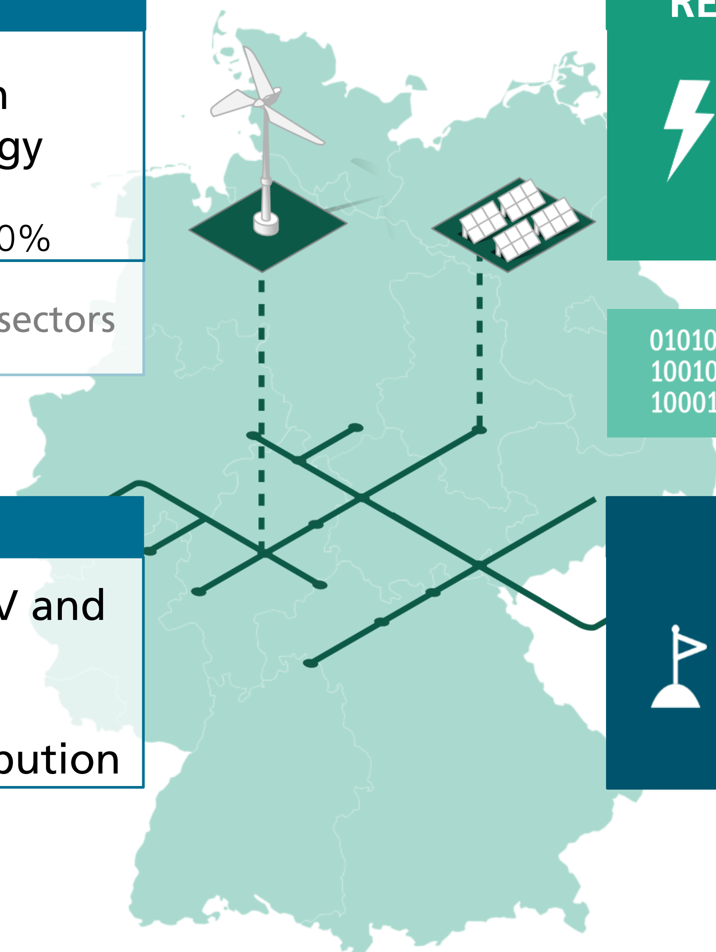
RES with power electronics

2% - 89% PV & Wind in electrical power

19.-21 may 2018

Digitalisation

01010
10010
10001



Decentralization

>60 GW RES in LV and MV grids

95% RES in distribution

Autarky

> 100.000 PV-Battery-Systems

Distributed PV and Wind Energy are system relevant

Challenge and Vision

Challenge:

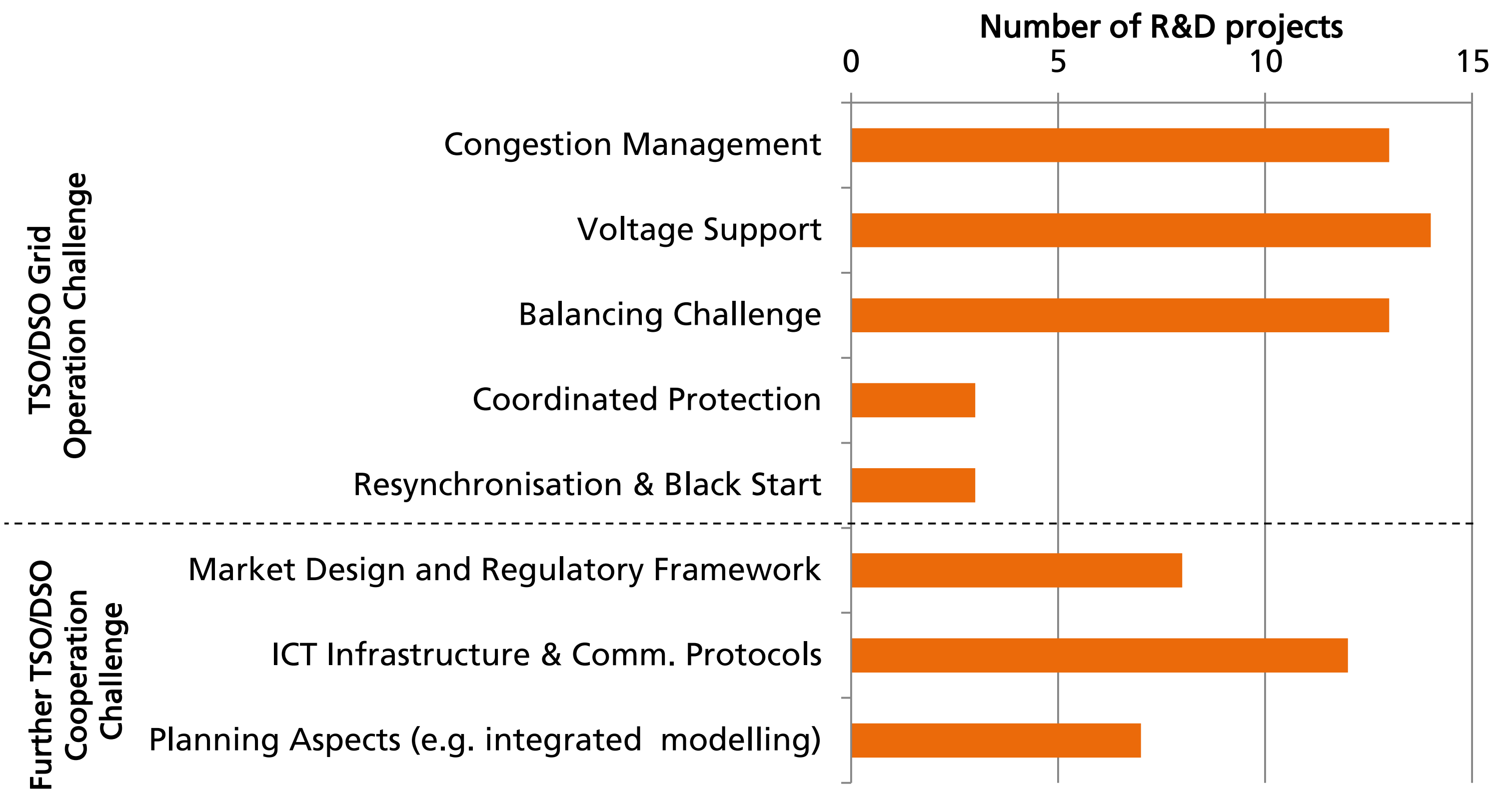
- Decentralization
- Request for additional ancillary services from distributed generation (large number, spatially distributed, temporal uncertainties)

Vision:

- Reliable, secure and effective grid operation with a high penetration of DER units
- DSO 2.0 controls DG → supports system stability (more responsibility)
- Ancillary services from DSO to TSO (e.g. PQ flexibilities , blackstart support)

TSO/DSO cooperation challenges

Scope of identified 19 R&D projects on advanced TSO/DSO cooperation
(multiple scopes per R&D projects possible) (preliminary)



Source: IEA PVPS Task 14 report: International R&D Project Collection – Advanced Cooperation between Distribution and Transmission Network Operation, (to be published), visit: http://www.iea-pvps.org/

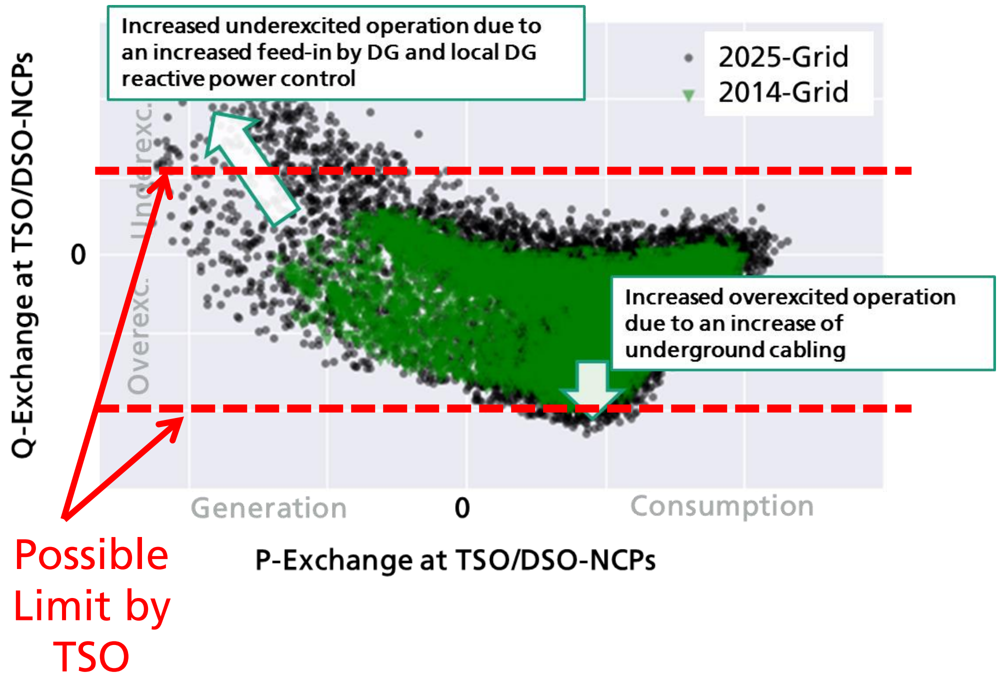
Example reactive power provision from DSO to TSO

Example: PQ - requirements at TSO/DSO interface, present situation in Germany:

- Challenge for the DSO to fulfill PQ-requirements at TSO/DSO interface
- Situation can become worse because of DG expansion, grid expansion or local DG reactive power control

Solutions e.g.:

- **Installation of additional compensators**
- **Q provision by DGs in the distribution grid**
- Q provision by planned HVDC inverters
- Modification of power plants for phase shift operation



Example annual PQ-Exchange at TSO/DSO-NCPs for a distribution grid section [1] (current status and expected future development) Courtesy of Bayernwerk AG

NCP = Network Connection Point

[1] Kraiczy M. et al.: Gesicherte und dargebotsabhängige Blindleistungsbereitstellung durch Erzeugungsanlagen im Verteilnetz, Zukünftige Stromnetze für Erneuerbare Energie, Berlin, Januar 2017

Reactive power provision from DSO to DSO

Example:

at Fraunhofer IEE we **develop and test Q-management algorithms** taking into account renewable distributed generators (DGs)!

General approach:

- LV-grid: local Q-control
- MV-grid: combined central and local control
  - Local control: fast and autonomous voltage support by MV-DGs
  - Central control: overall Q-management by MV-DGs

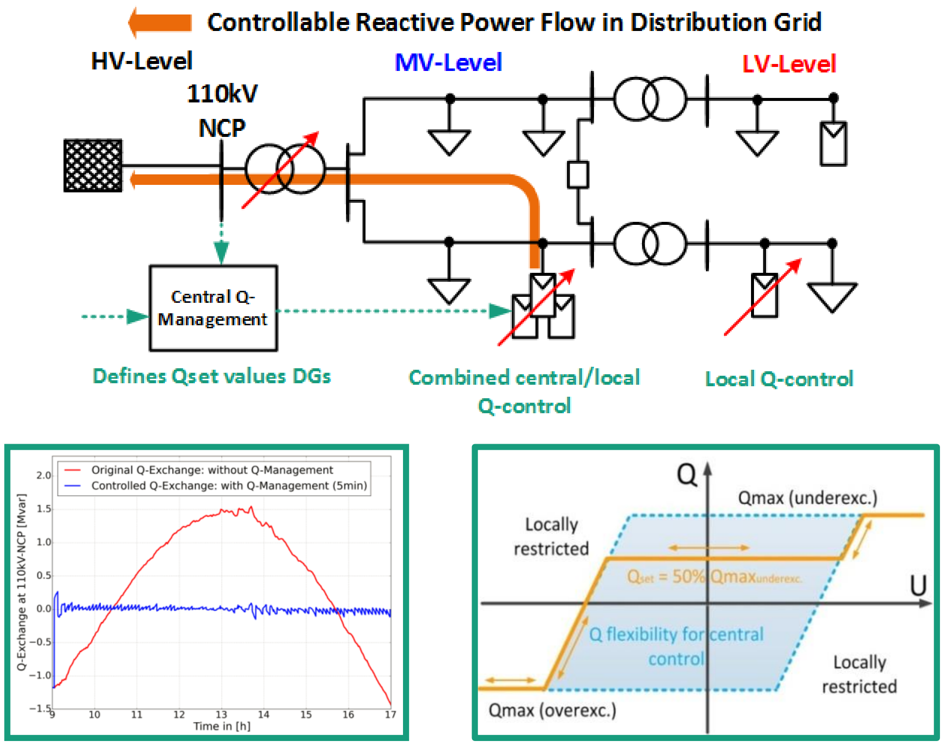


Fig: top: Combined central/ local Q-control approach [1], bottom left: example HiL-results [1], bottom right: Requested combined local/central approach by a German DSO [2] (Courtesy of Bayernwerk AG)

[1] H. Wang, et al."Controlled Reactive Power Provision at the Interface of Medium- and High Voltage Level: First Laboratory Experiences for a Bayernwerk Distribution Grid using Real-Time-Hardware-in-the-Loop-Simulation," VDE ETG Congress, Bonn (Germany), 2015

[2] Bayernwerk AG, "Technische Richtlinie Erzeugungsanlagen am Mittelspannungsnetz der Bayernwerk AG, Juli 2008." July 2015

SysDL 2.0 (Finalist ISGAN Award of Excellence 2018)

Ancillary services from area distribution grids and distributed RES for the TSO

DSO

- Drewag NETZ GmbH (consortium manager)
- ENSO Netz GmbH
- Mitteldeutsche Netzgesellschaft Strom mbH

TSO

- 50 Hertz Transmission GmbH

Research institutes

- Technical University Dresden
- Fraunhofer IEE
- Kassel University

Technology company

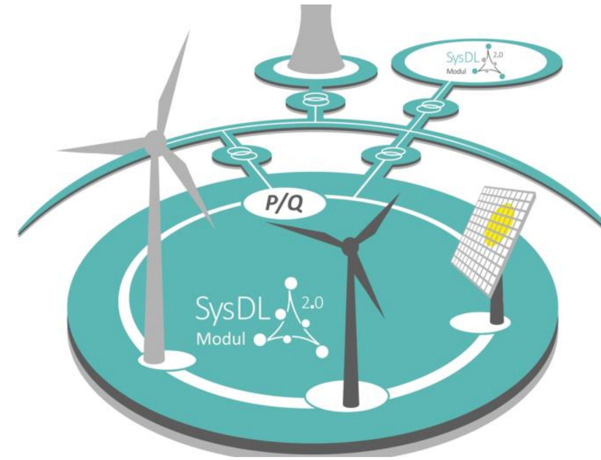
- Siemens AG

Small and medium sized business

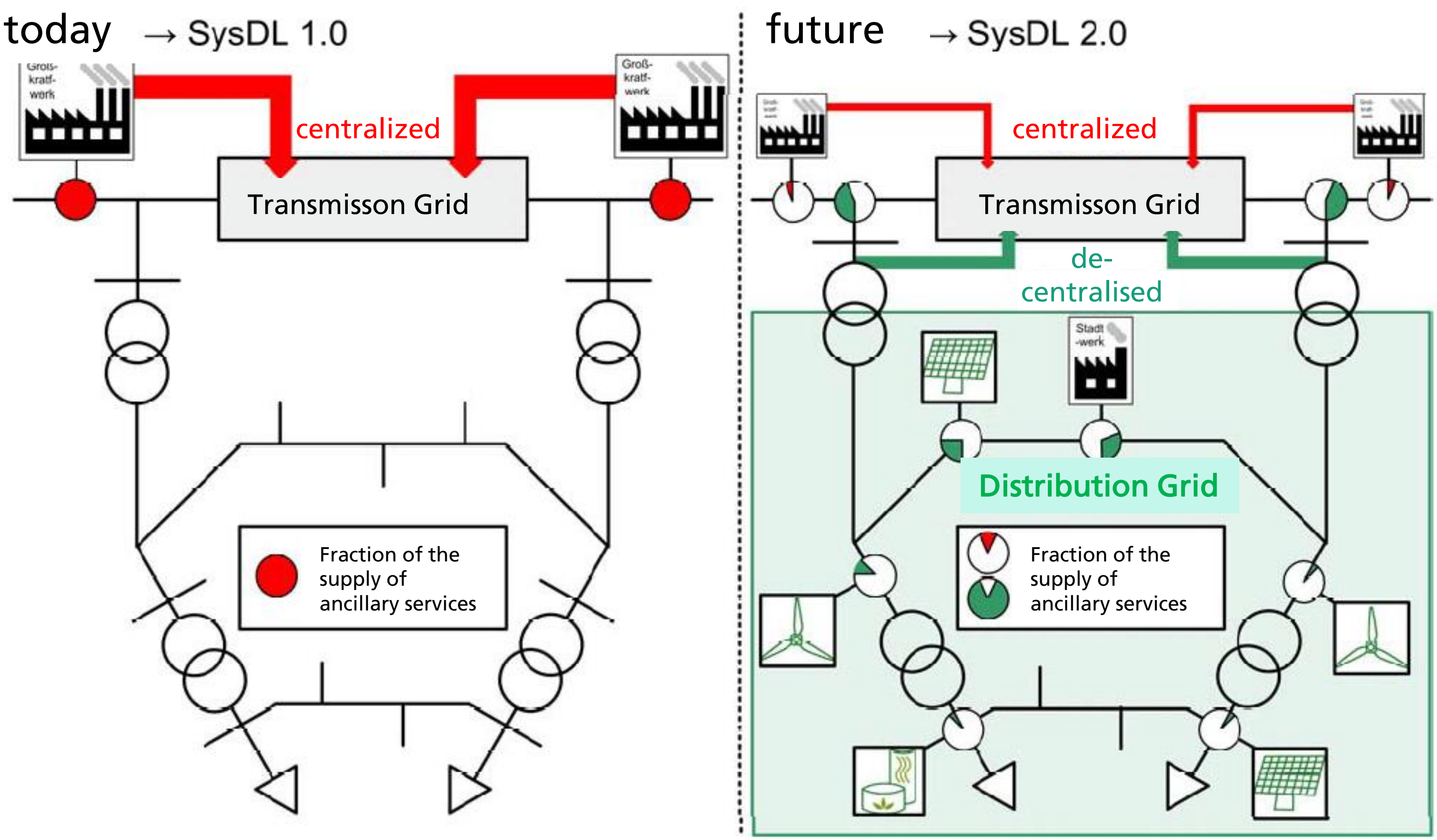
- Fa. F&S Prozessautomation GmbH

Associated partners

- TEN, DNV GL



DSO 2.0 supplies ancillary services to TSO



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Organisation of the TSO/DSO interface

Example: Project „SysDL 2.0“

www.sysdl20.de

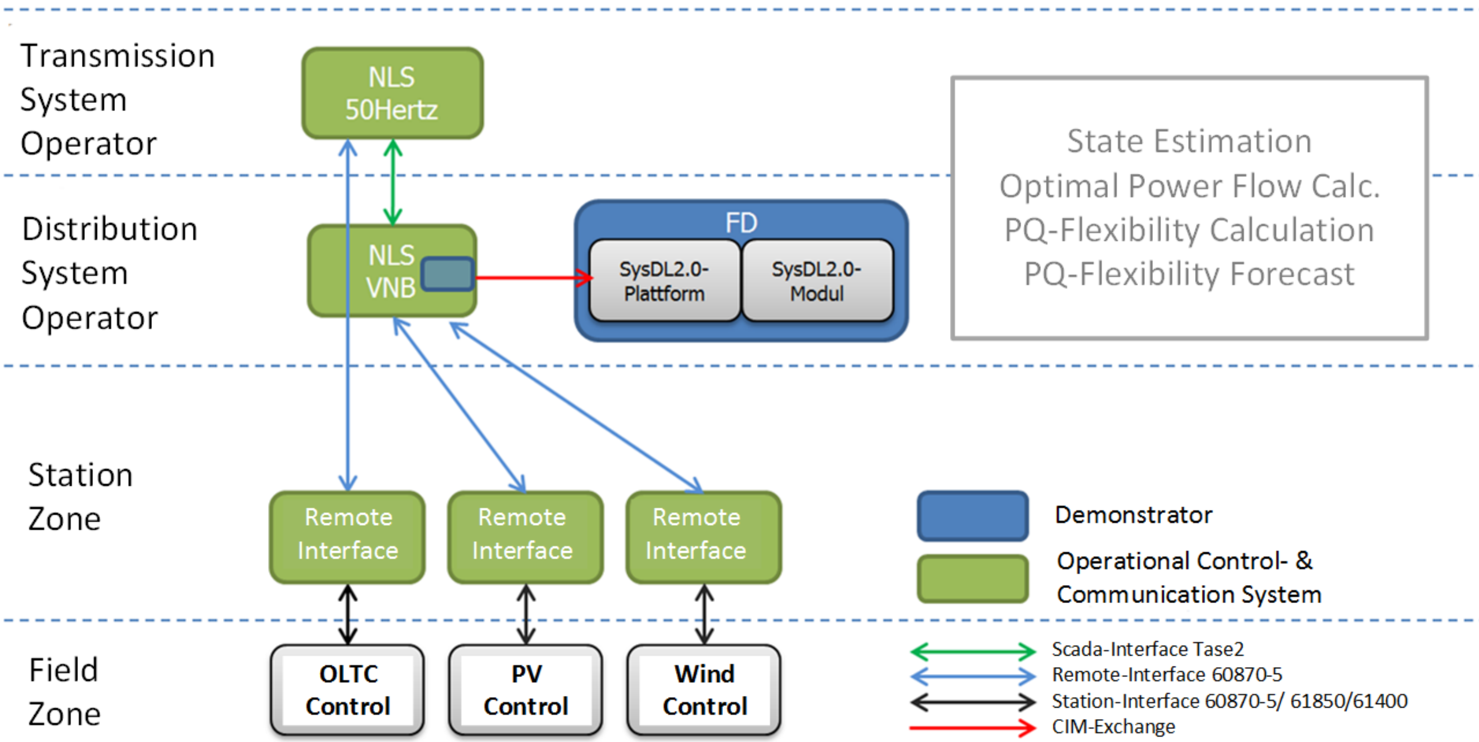

Image source: Project SysDL 2.0 (http://www.sysdl20.de)

Organisation of the TSO/DSO interface

Example: Project „SysDL 2.0“

www.sysdl20.de

- DSO aggregates information about RES flexibilities via the SysDL 2.0 demonstrator
- Data exchange via CIM CGMES between DSO and demonstrator
- Results are provided via a web based interface (input and output)
- TSO can access this web interface remotely and the communicate with DSO

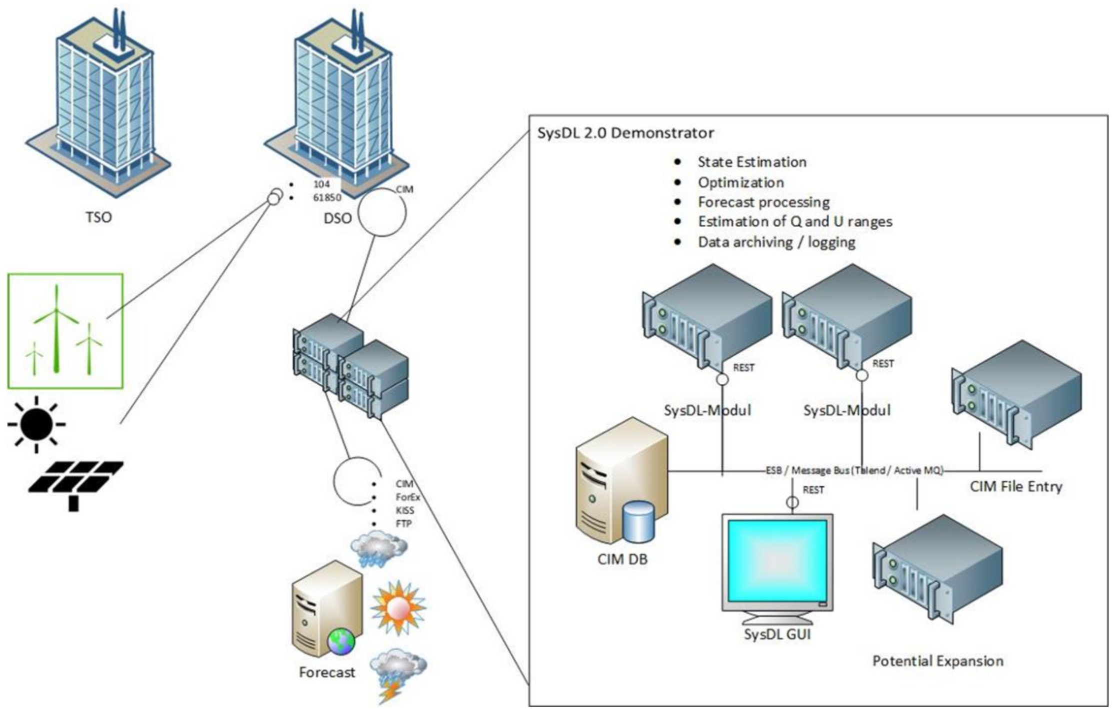

Image source: Project SysDL 2.0 (http://www.sysdl20.de)

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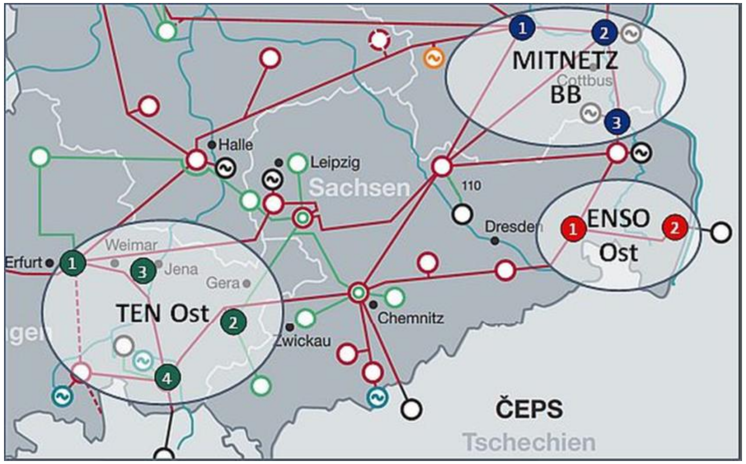
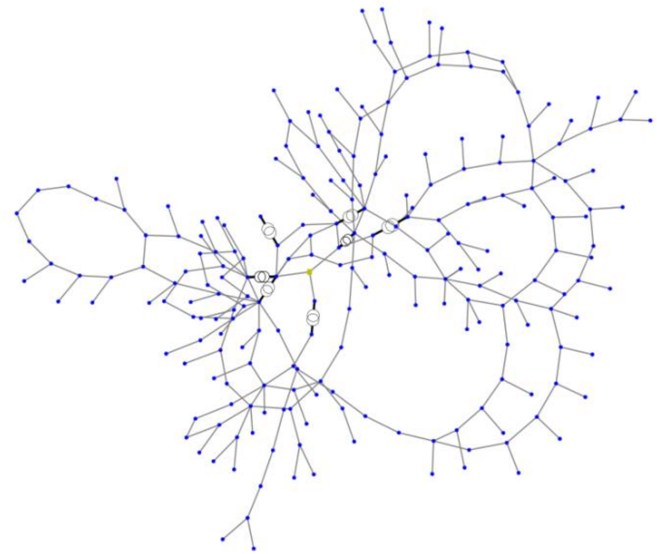
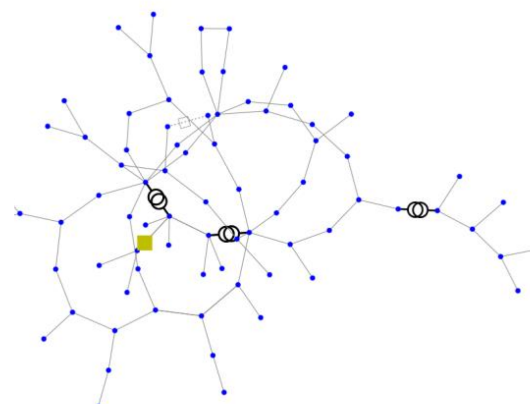
Grid topology and size of investigated networks

in real time simulation and field test





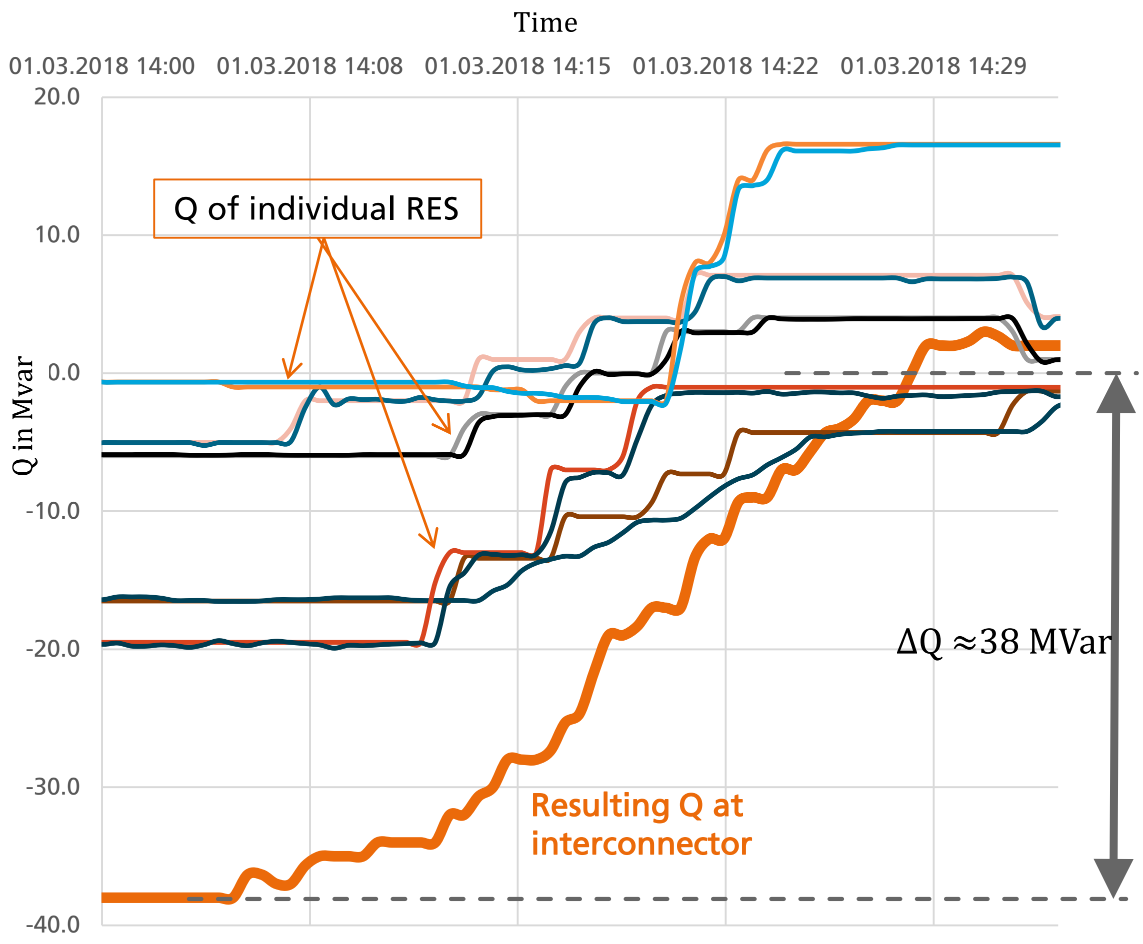


Elements	Mitnetz	ENSO
# Buses	200	80
# Lines	230	90
# HV/MV substations (loads)	70	50
# Generators (wind + PV)	50 (30 + 20)	6 (5+1)
# Interconnection points	3-5	2
# EHV/HV transformers	10	4

DSO – TSO Interaction

Results from the field test

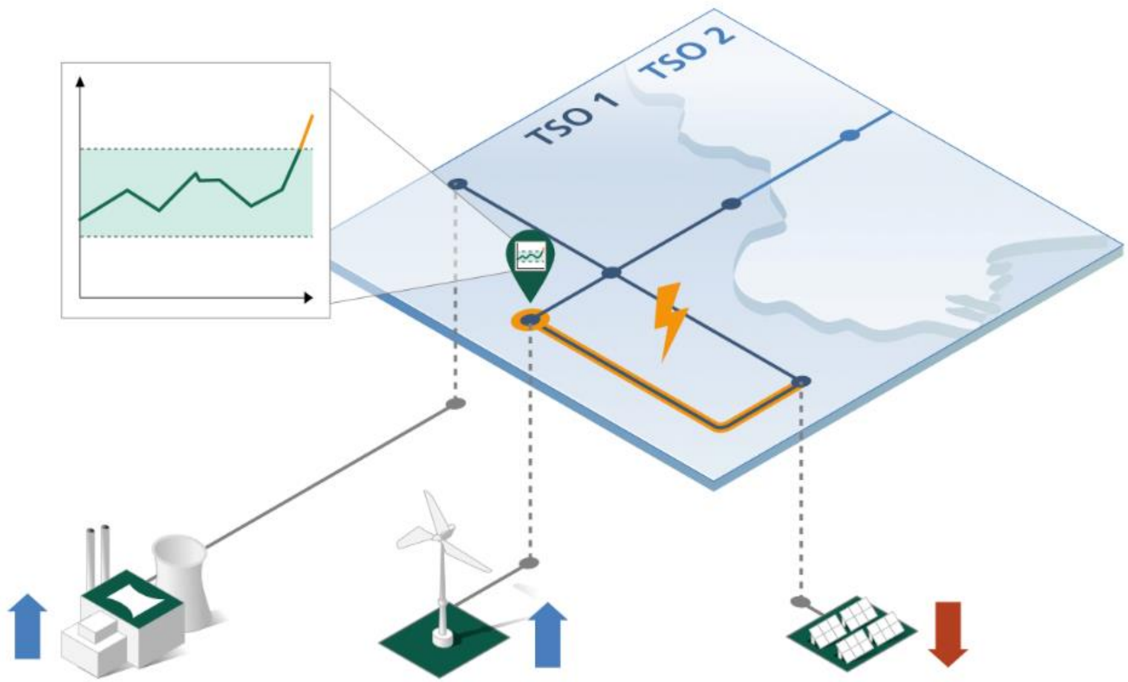
1. DSO forecasts (next 4 hours) potential Q-range
2. TSO selects set-point from Q-range
3. DSO received set-point for interconnection point Q = 0
4. Optimization determined set-points for RES
5. Operator entered them manually in steps of 3 Mvar per 2 min (colored lines)
6. After 30 minutes, the desired set-point at interconnector was reached (dashed line)



Successor project of SysDL2.0: EU-SysFlex

Determination of active power flexibilities from DER in distribution grids

- Development of algorithms to determine active power flexibilities of DER in distribution system
- Further development and automatization of reactive power flexibility determination
- Developement of an innovative state-estimation based on ANN
- Closed-loop connection between system platform and DMS



http://eu-sysflex.com/

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Optimized grid operation

in power systems with high penetration of renewables

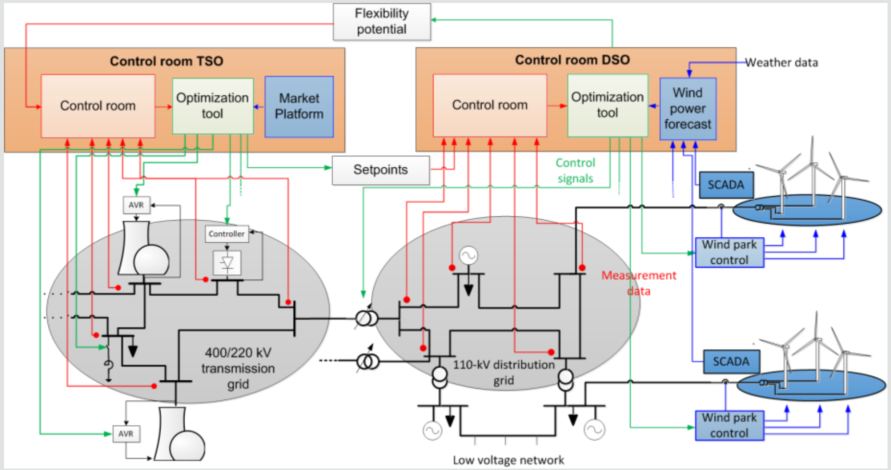
Example: Increased demands on optimization and coordination between TSO & DSO due to changed generation location

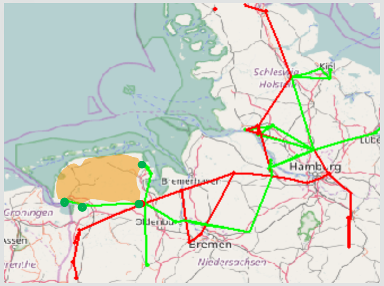
Implementation of optimization tool to coordinate and enhance TSO-DSO-interface

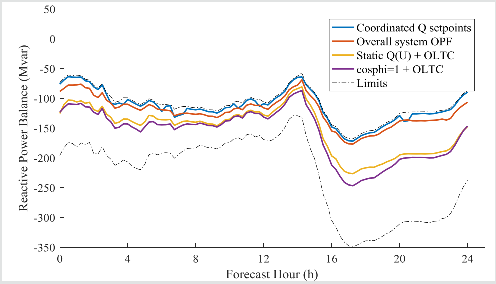
- Optimization on DSO-level to provide flexibility potential at interface to TSO
- Optimization on TSO-level using own and TSO-flexibilities and giving setpoints to DSO
- DSO uses RES flexibilities to provide setpoints and new flexibility potentials

Study case:

- Larger DSO area in northern Germany with high share of RES
- (Part of) German transmission grid
- Reactive power provision in given limits using different approaches





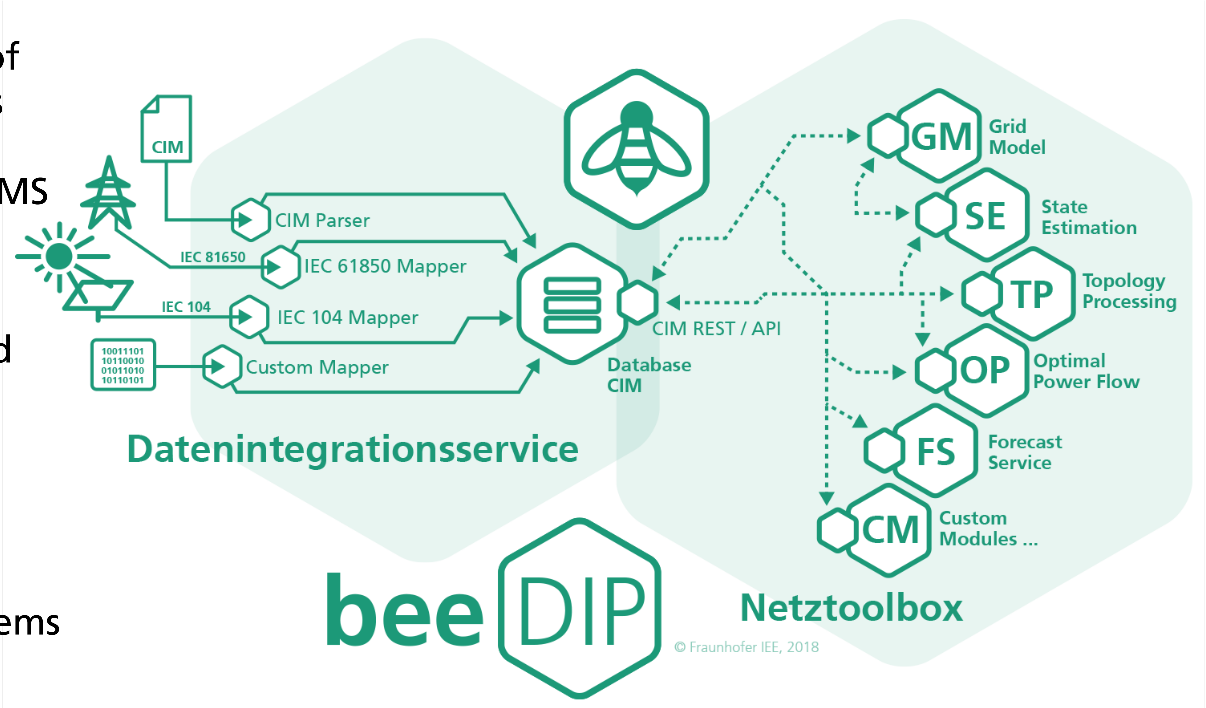


D. S. Stock, F. Sala, A. Berizzi, and L. Hofmann, “Optimal Control of Wind Farms for Coordinated TSO-DSO Reactive Power Management,” Energies, vol. 11, no. 1, p. 173, http://www.mdpi.com/1996-1073/11/1/173/pdf, 2018.

Fraunhofer IEE Demonstrator Plattform beeDIP

Grid toolbox

- Environment for integration of internal and external modules and functions (higher order functionalities) for usage in DMS
- Independent of programming languages due to modular architecture (micro service and REST)
- Sustainable platform due to modifiable content
- Useable to integrate research results in already existing systems

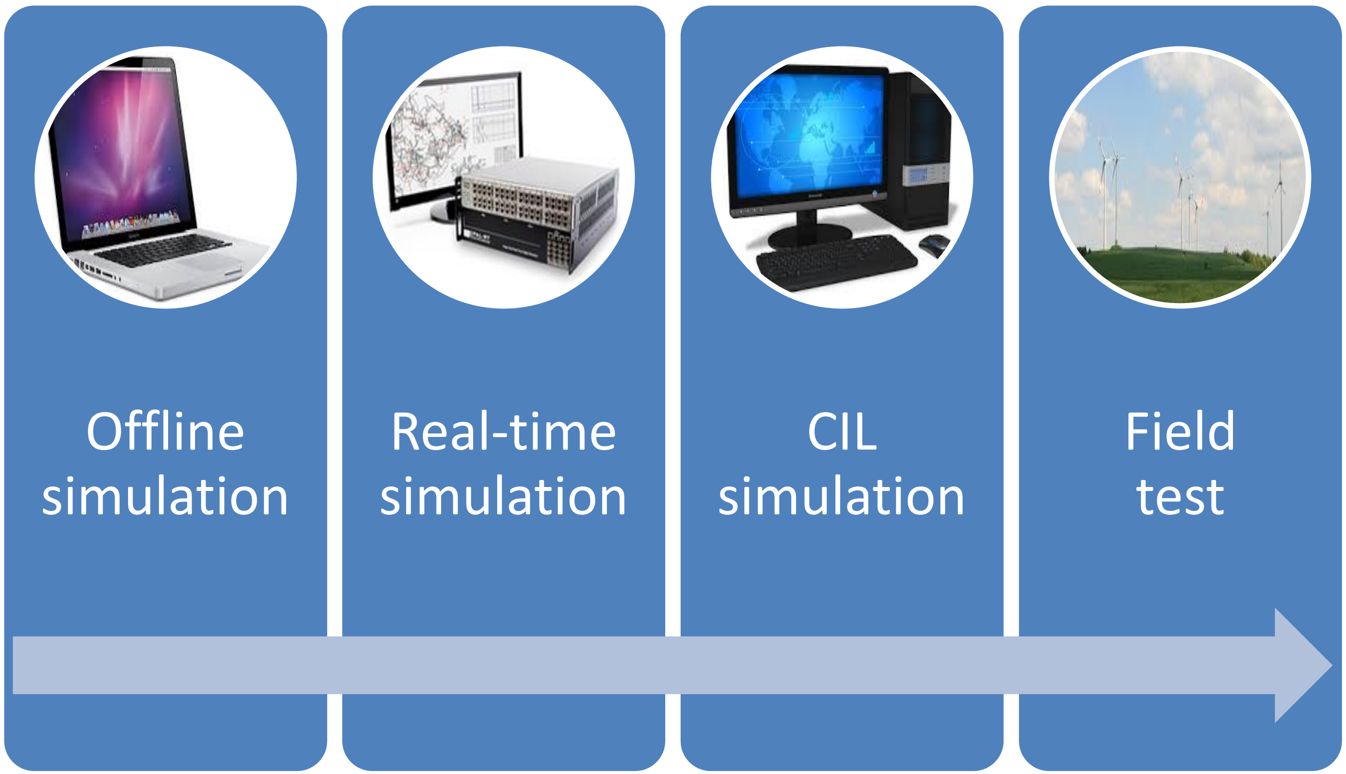


Data integration service

- Internal usage of pandapower, CIM CGMES[1] and standardized interfaces
- general access on module results and data via REST[2] API
- Integration and Aggregation of different data sources (forecast, measurements, topologies, ...)

[1]Common Grid Model Exchange Standard, [2]Representational State Transfer

From concept over laboratory to field

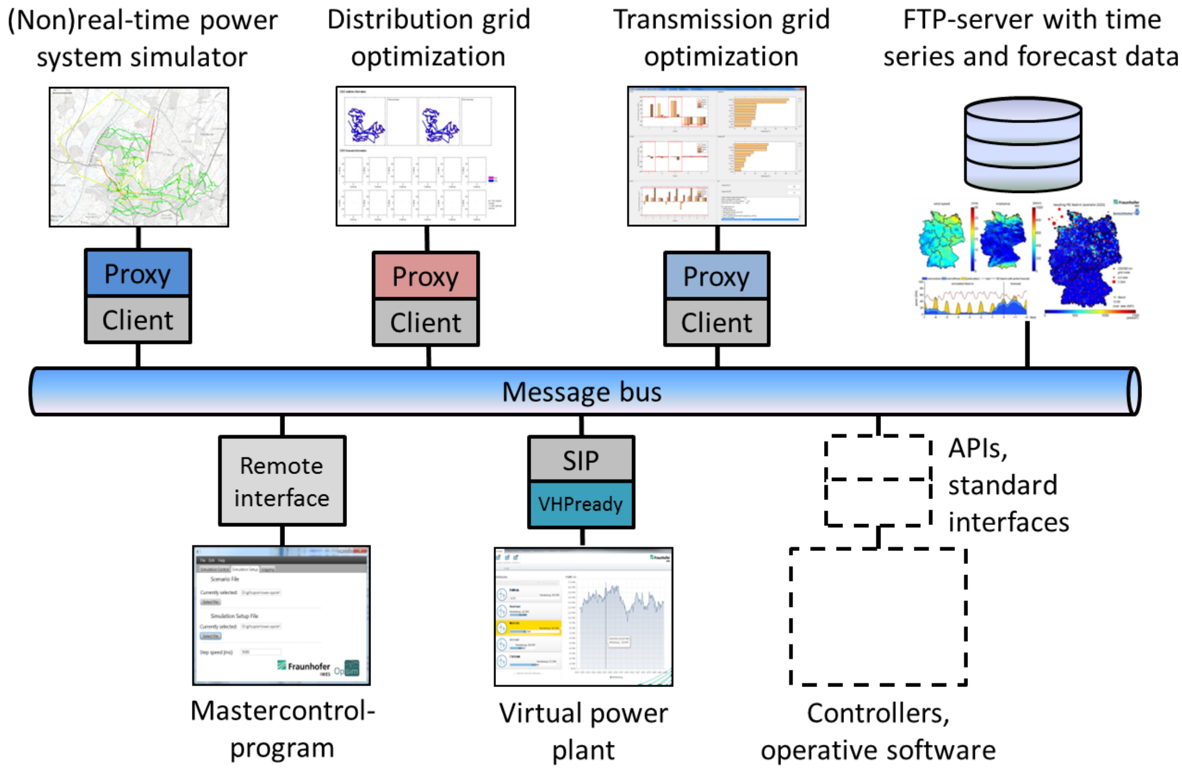


The OpSim platform

www.opsim.net/en

What is OpSim?

a flexible co-simulation platform, consisting of a message bus and a proxy / client architecture(*) in Java.



(*) Concept: Faschang, M.; Kopzug, F.; Mosshammer, R.; Einfalt, A.; Proc. IECON 2013

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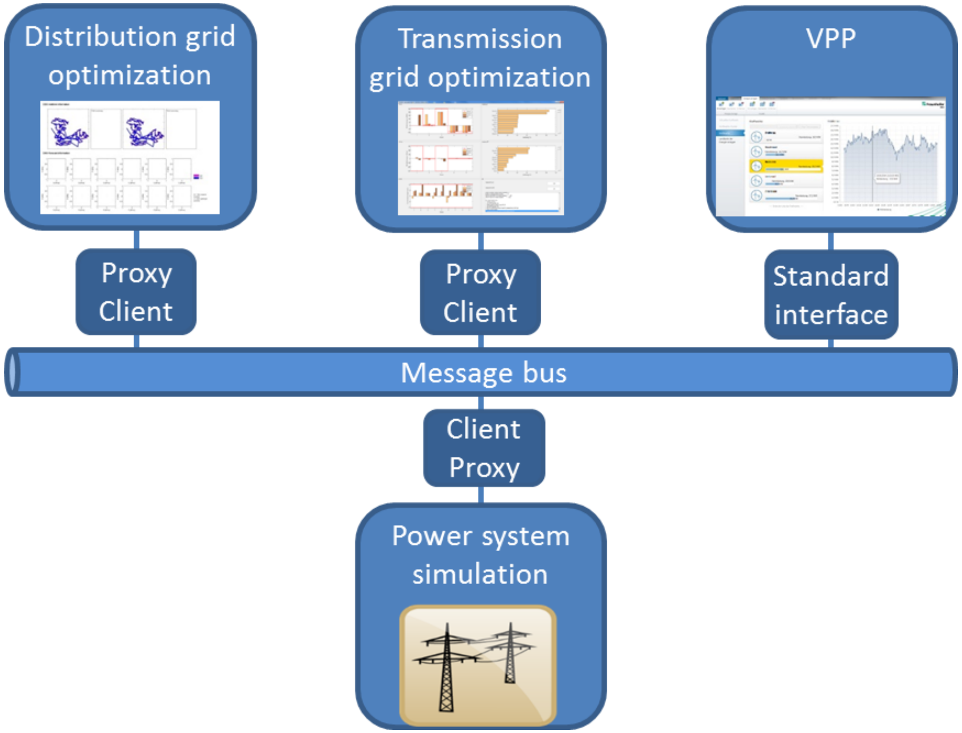
The OpSim platform

www.opsim.net/en

Why co-simulation?

- We can study interactions between multiple grid operation strategies (= optimizers)!
- Or investigate interactions between grid control algorithms and virtual power plant software!

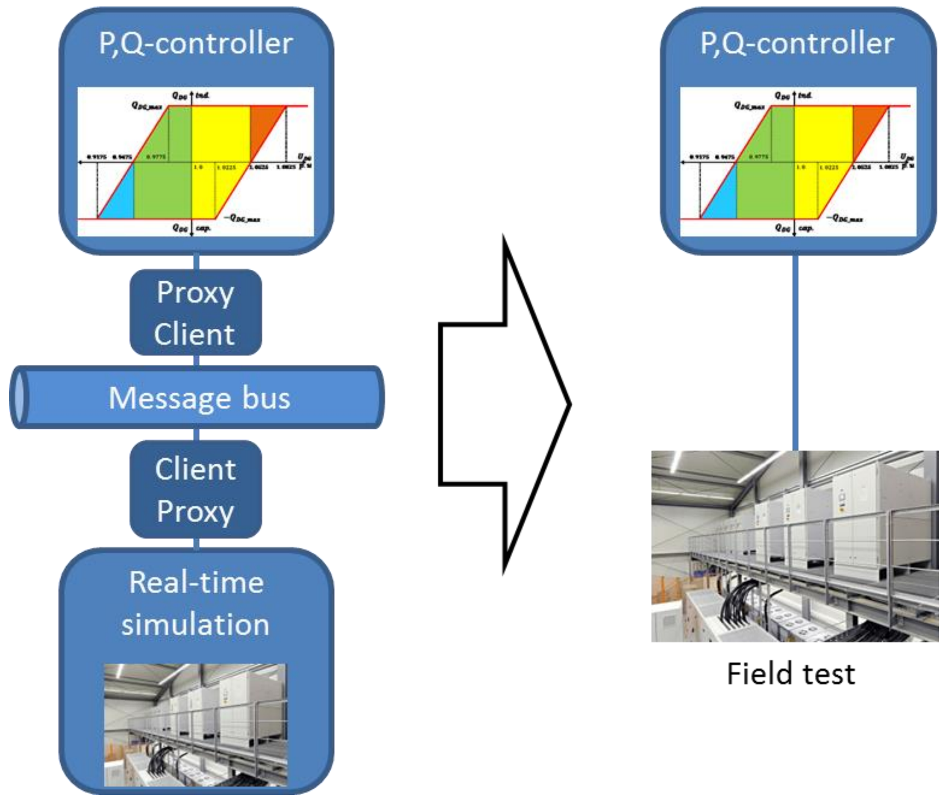


The OpSim platform

www.opsim.net/en

Why co-simulation?

- We can study interactions between multiple grid operation strategies (= optimizers)!
- Or investigate interactions between grid control algorithms and virtual power plant software!
- We can test our PQ-management algorithms in real-time, prior to field testing!

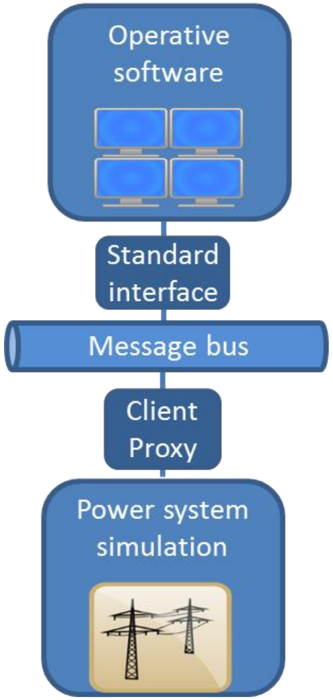


The OpSim platform

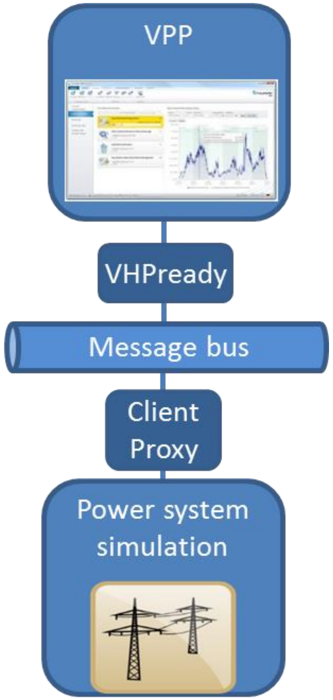
www.opsim.net/en

Interfaces crucial

- Standardized interfaces (CIM, IEC61850, IEC 60870-5-104, VHPready) allow **tests of operative software in real-time**!
- A HTTP-interface enables **spatially separate**, but causally correct co-simulations with external partners!



Example:



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The OpSim platform

www.opsim.net/en

Interfaces crucial

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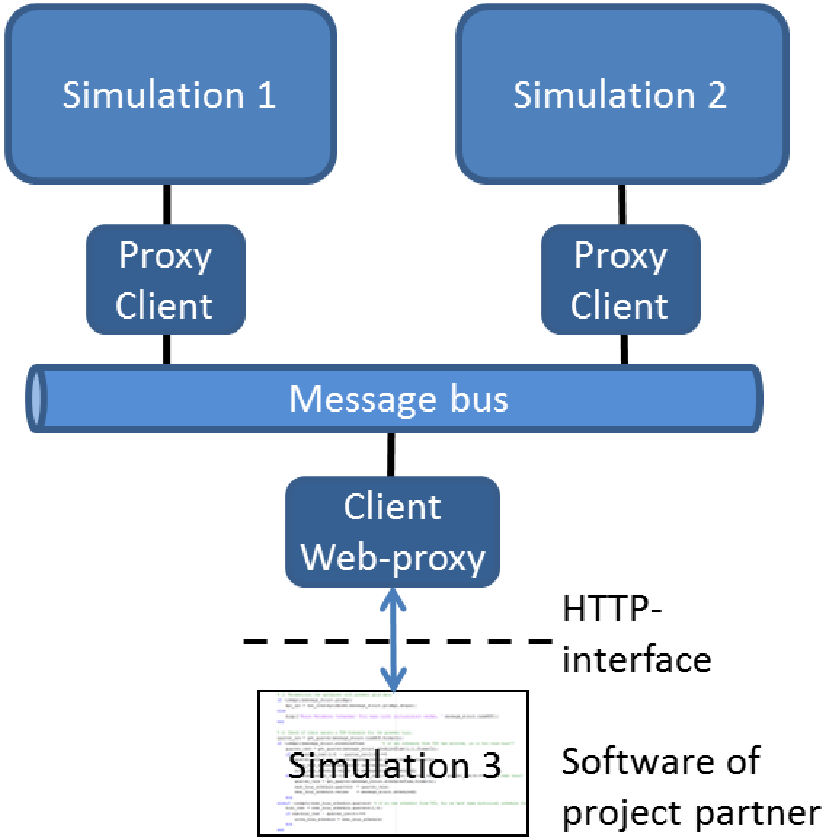
- A HTTP-interface enables **spatially separate**, but causally correct co-simulations with external partners!
- HTTP-interface could also be used **without any simulations from IEE,** purely by external partners. (OpSim “as a service”)

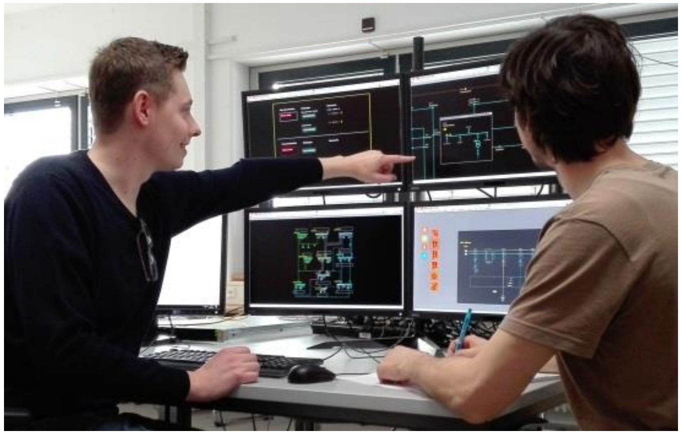


The OpSim platform

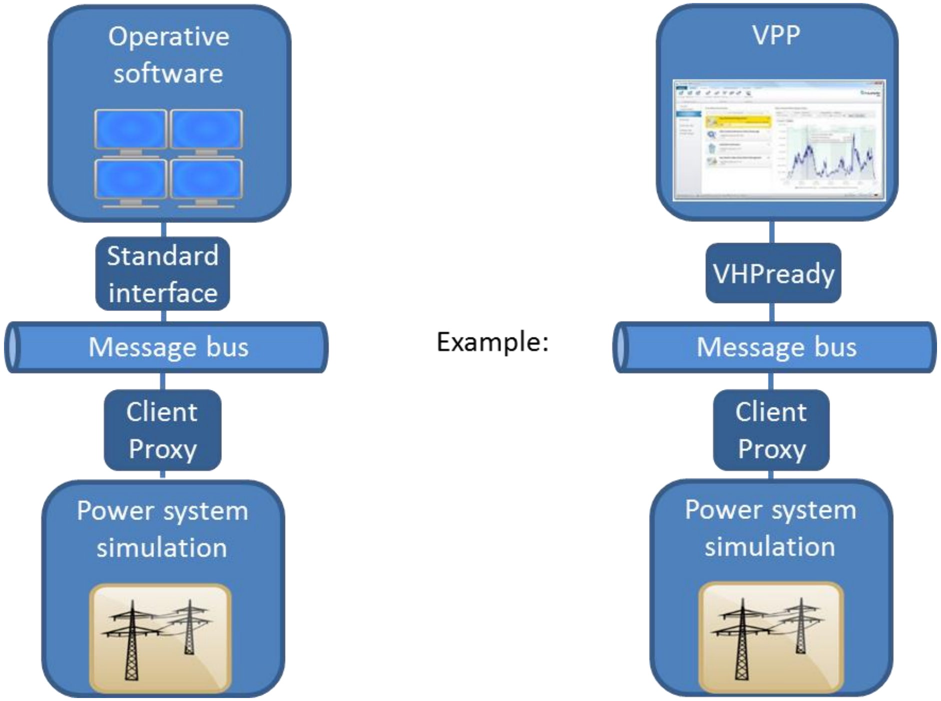
www.opsim.net/en

Examples

- VPP-software from Bosch
- DMS-/VPP-software from Fraunhofer IEE
- DMS-software from PSIcontrol

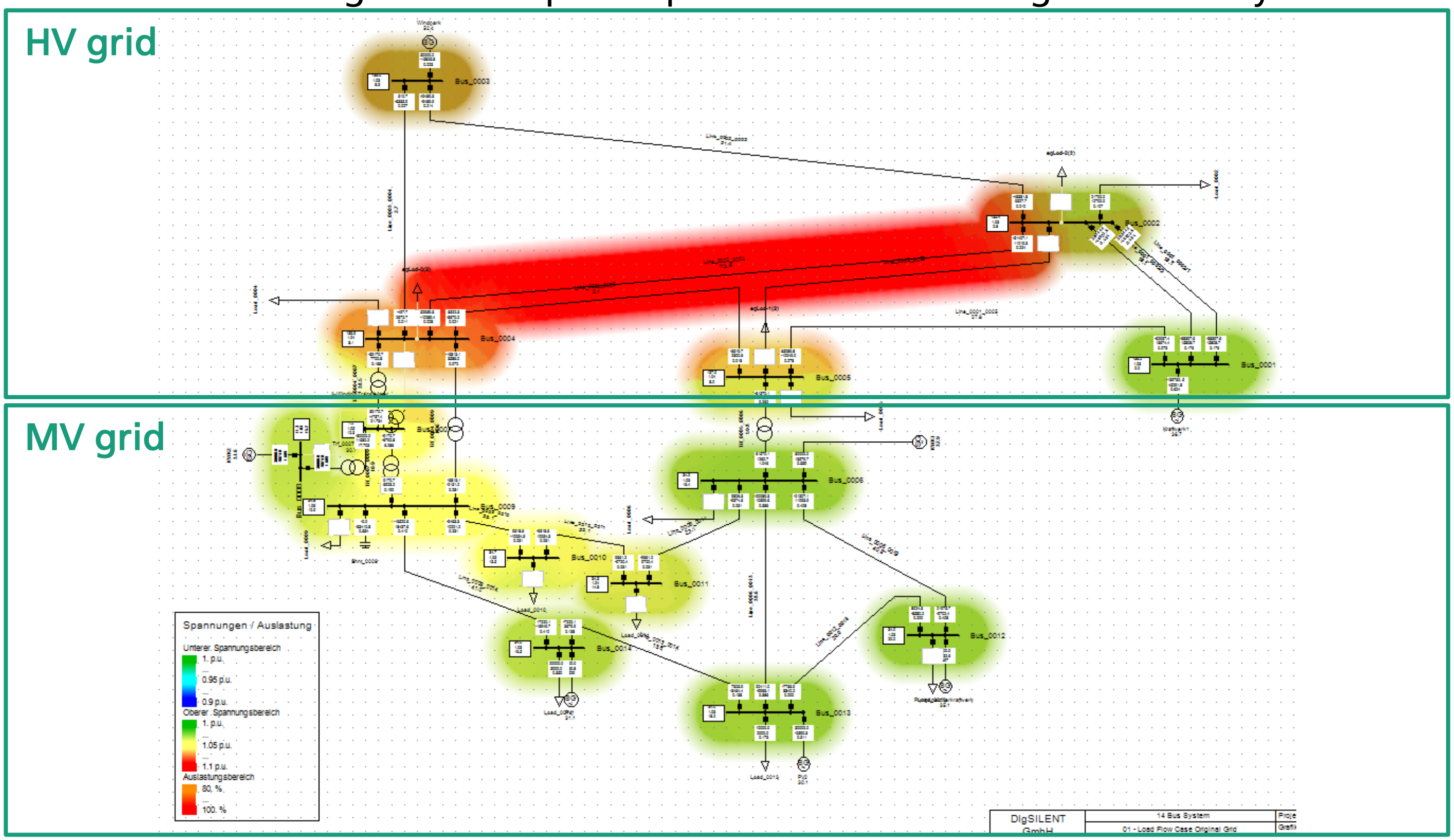


OpSim control center



OpSim simulation of cascaded TSO → DSO → DSO processes
(project example: SINTEG c/sells)

- Congestion in high voltage (HV) grid!
- The congestion cannot be solved alone by measures in the HV grid.
- "Cascaded" downregulation of power plants in HV and MV grid necessary!



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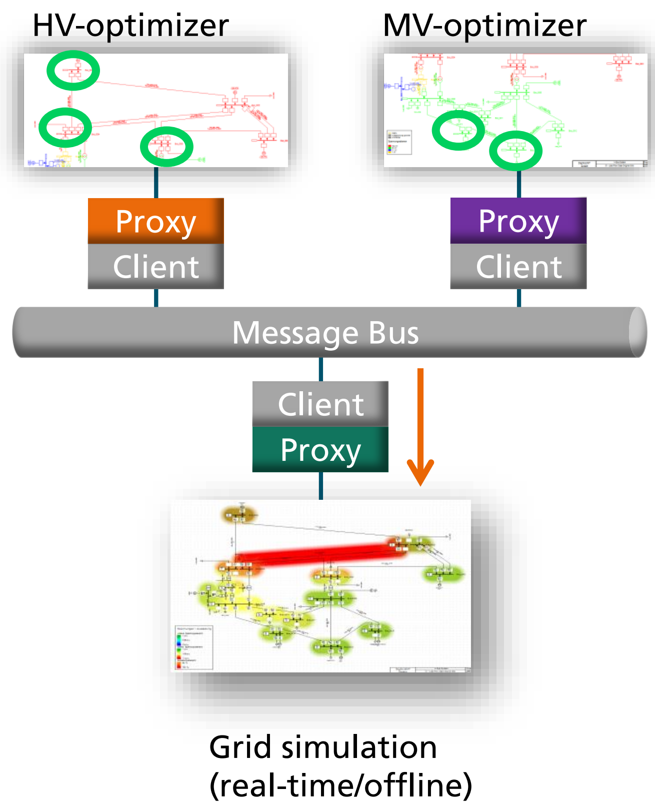
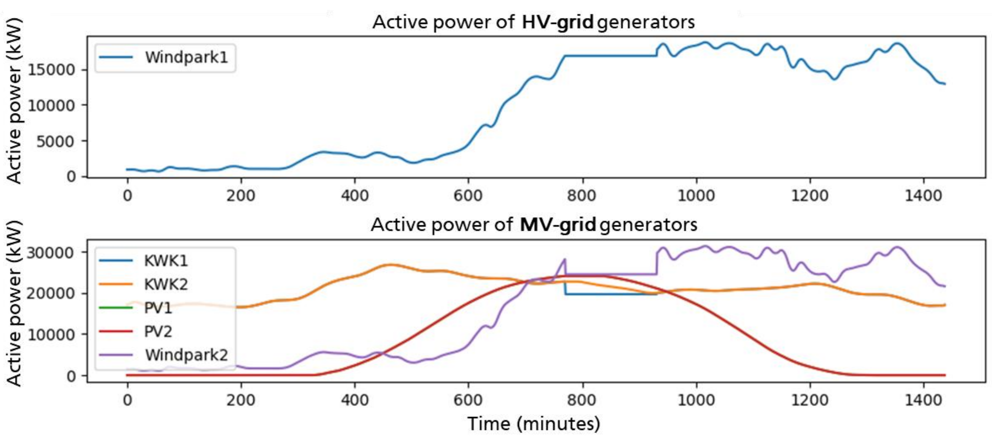
OpSim simulation of cascaded TSO → DSO → DSO processes (project example: SINTEG c/sells)

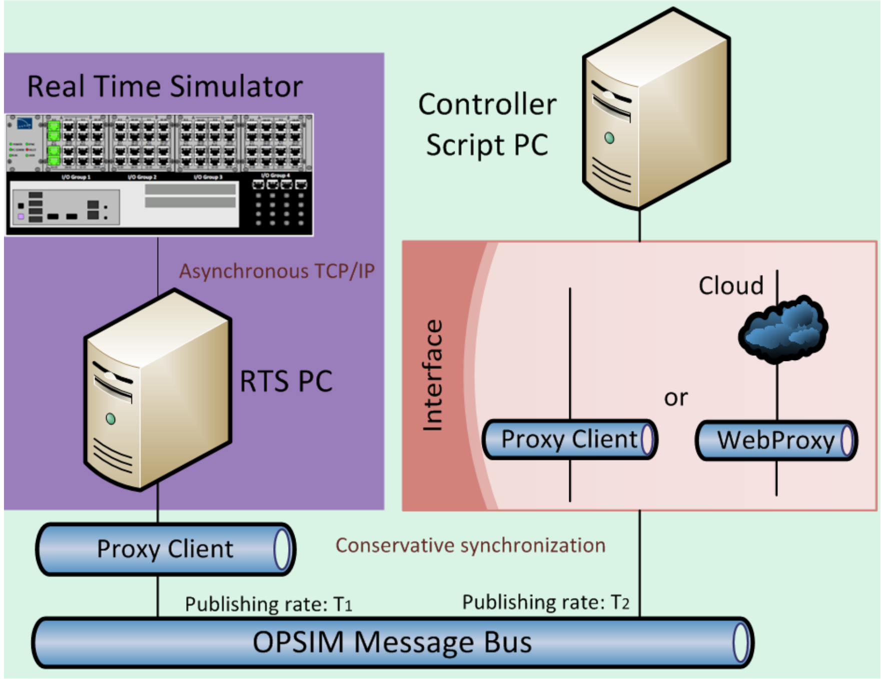
1. Congestion occurs in grid simulation.
2. HV-optimizer computes **sensitivity factors** (for controllable HV-generators or HV-loads) that could resolve the congestion.
3. MV-optimizer also receives a cascaded **P-reduction set point** from the HV-optimizer and computes how to fulfill it using MV-generators.
4. Both optimizers send their P-reduction set points to the grid simulation -> result of cascade!





OpSim as a service

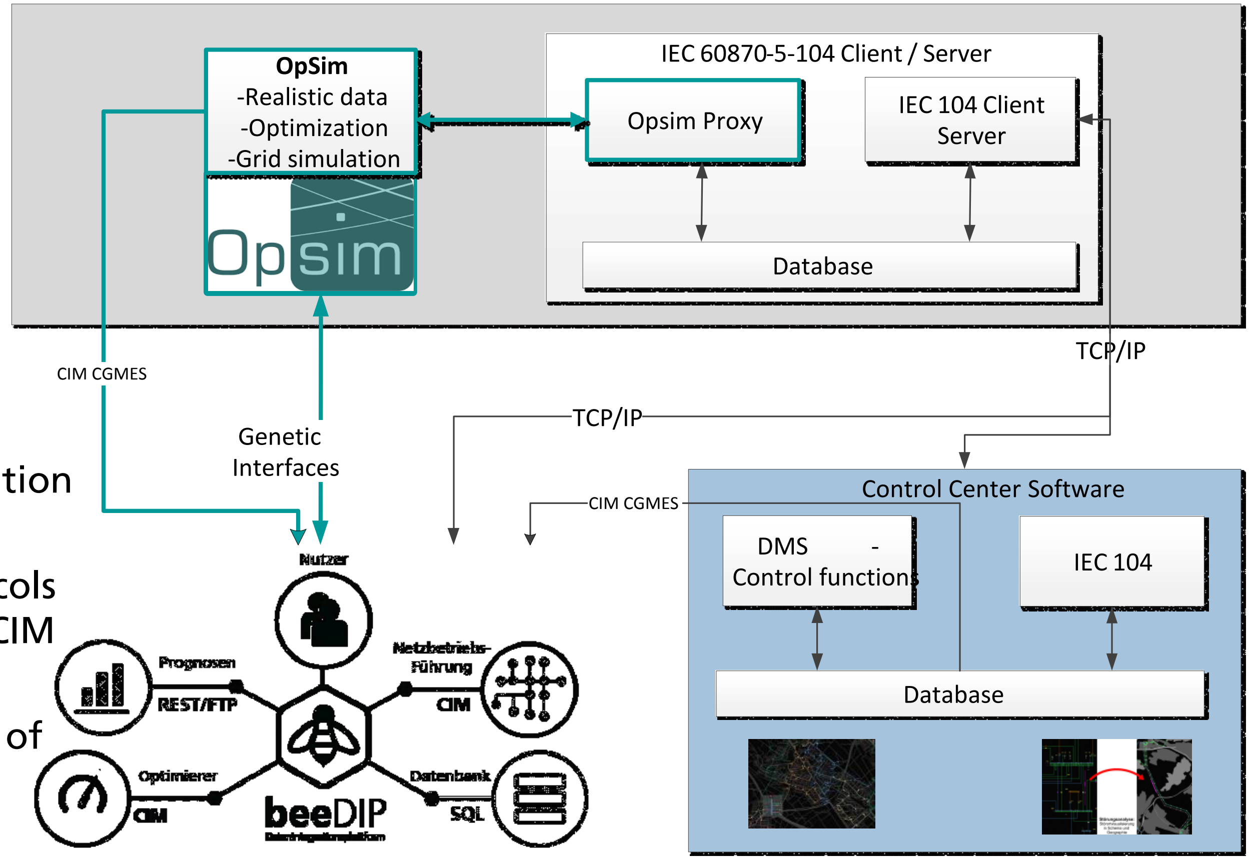
- In the EriGrid project [1], OpSim is used to connect international research laboratories.
- A voltage controller PC located in Athens, Greece, is connected to a real-time grid simulator in Kassel, Germany [2].
- In this way, real-time control algorithms can be tested by (inter)national partners, before they go into field tests.
- Due to PHIL-capability of real-time simulator, this architecture also allows for remote PHIL-experiments!



[1] https://erigrid.eu/ , [2] J. Montoya, R. Brandl, M. Vogt, F. Marten, M. Maniatopoulos; Asynchronous Integration of a Real-Time Simulator to a Geographically Distributed Controller through a Co-Simulation Environment, IECON 2018

Real labs with OpSim and beeDIP

- Realistic replication of communication
- OpSim: Grid simulation, controller prototypes and scenarios
- beeDIP: Platform for implementation of new functionalities via standardized interfaces
- DMS: Replication of real functionalities and communication
- tests of communication via standardized interfaces, protocols and data models (61850, 104, CIM CGMES)
- Information of different levels of detail via DMS interface and direct simulation
- Test and validation of new innovative methods and processes in a realistic DMS environment



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Conclusions

- Ancillary / system services will be innovated by making use of distributed energy units and their control flexibilities
  → new operational strategies, DSO-DSO-TSO communication
  - New concepts (hierarchies, degree of decentralization etc.)
  - New solutions (interfaces, protocols, interactions, markets etc.)

  → Test platforms required for realization: **beeDIP**

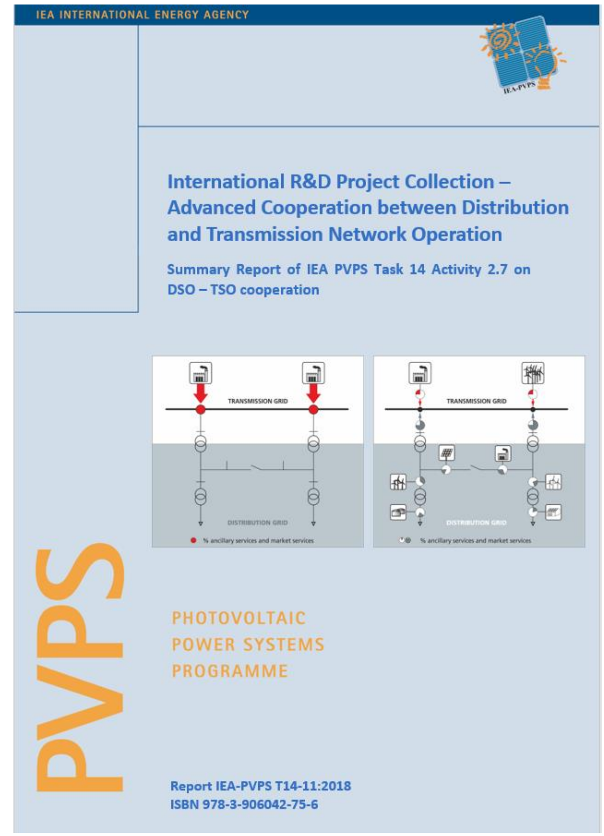
  → Co-simulation / CIL platfom required for system analyses: **OpSim**

- Cooperation between R&D partners necessary
  → Co-simulation (real-time, online, offline)
  → Simulation as a service with OpSim

IEA PVPS Task 14 Report (upcoming)

International R&D Project Collection – Advanced Cooperation between Distribution and Transmission Network Operation

- Collection of 19 international R&D projects from the U.S., Europe and Japan with a focus on advanced TSO/DSO cooperation
- Overview on scope, objectives, key findings and recommendations of the identified R&D projects
- Collection of experiences and discussion on the technology readiness level for the provision of ancillary services by PV
- Latest IEA PVPS reports: http://www.iea-pvps.org/



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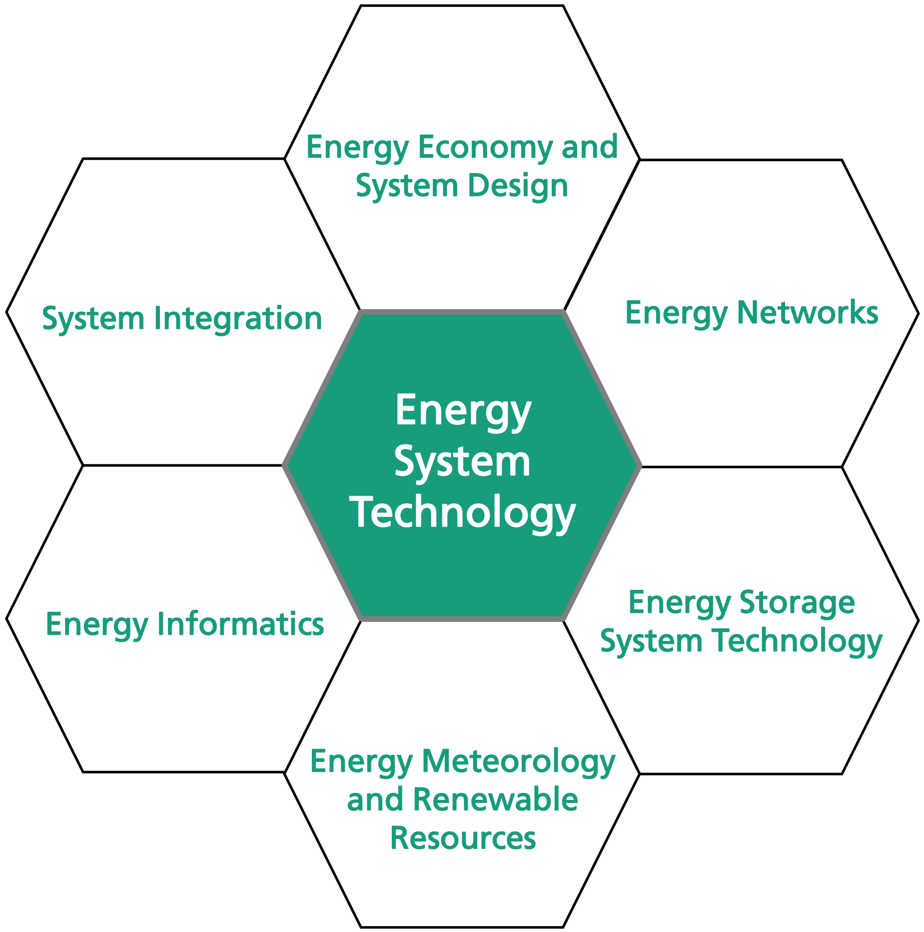
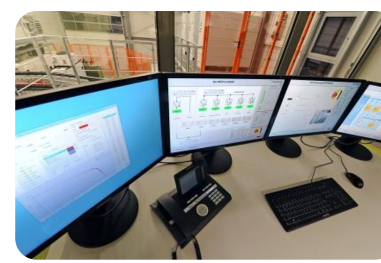
Energy system technology to realize the 'Energiewende'





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Fraunhofer IEE– Business Field Grid Planning and Operation

- Techno-economic studies for analyzing, planning, operation, control, stability of power systems
- Automated planning tools
  www.pandapower.org
- Operational tools (algorithms for ancillary services, hardware/software test platform)
- (Co-simulation) test platforms for operational solutions
  www.opsim.net/en
- Multi-energy system planning and operation (power, heat, gas)
- Microgrid/ hybrid system test bench and PHiL tests

Energiemanagement und Betrieb elektrischer Netze

UNI KASSEL VERSITÄT

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Department e²n

Energy Management and Power System Operation

- Development of models, methods, algorithms and tools for analysis, operation and control, and design of the future decentralized power system with high share of renewable energies. e.g. www.pandapower.org
- Multi-Objective/Perspective/Level Optimisation of the power system
- Simulation of the power system over time scales and system levels.
- Resilient Control Design incl. power system stability, network restoration, microgrid structures