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Active distribution systems and distributed energy resources

11105

‘ZellNetz2050’ – A Concept for the Efficient and Effective Operation of Multi-Sector Web-of-Cells Energy Systems

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Motivation

- Trend of electrification: New loads, e.g. mobility and heat sector, increase the total demand that is supplied by additional RES.
- Main tasks of system operators: active power balancing and congestion management.
- Grid expansion to integrate last Kilowatthour is prohibitively expensive and would not be socially accepted.
- Flexible units may complement scarce infrastructure by adapting their power schedules.
- Large number of system participants and their peculiarities make technical and economic system operation increasingly difficult
- Current market design and congestion management schemes are reaching their limits, affecting the security of supply
- Therefore, new market and operational concepts must be developed

Issues to solve

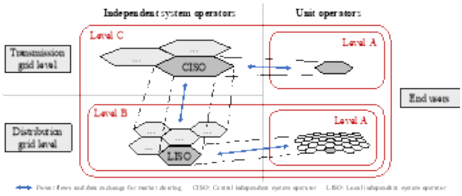
- Congestion management actions are used more frequent, complicating system operation
- As of today, local flexible units are not included in the market mechanism
- Local flexibility markets are prone to strategic bidding behavior
- Data exchange grows rapidly with the number of system participants, larger computation times for state estimation and market clearing are expected.
- Increasing uncertainty calls for quicker reactions in system operation

Web-of-Cells in ZellNetz2050

- Mitigating technical and economic challenges together
- Wholistic approach incorporating all system levels
- ‘Brown-field’ study based on existing infrastructure
- Division of the energy system into hierarchically ordered cells
- Specific market and operational concepts included

Energy Cells

- Integrated multi-carrier energy systems
- Energy cells are based on geographical area of energy infrastructure, i.e. existing network topology
- Vertical delimitation is based on system levels
- Hierarchically ordered
- Communication interaction is limited to directly adjacent energy cells
- Examples: households, industrial plants, medium-voltage electrical grid, wind farm, conventional power station
- Definition deliberately open to accommodate as many configurations of energy systems as possible to ensure interoperability, compatibility, and attainability



Structure of the Web-of-Cells-System

- Basic distinction betweeen “end-user” and “grid”
- End-user: Distinct area of responsibility, typically private property, connected to either the distribution or transmission level of one or more energy grids (Level A)
- Distribution grid: Intermediate system level with connections to end-users as well as the transmission level (Level B)
- Transmission grid: superordinate system level with responsibility for the overall energy system, connects both to distribution grids as well as large end-users (Level C)

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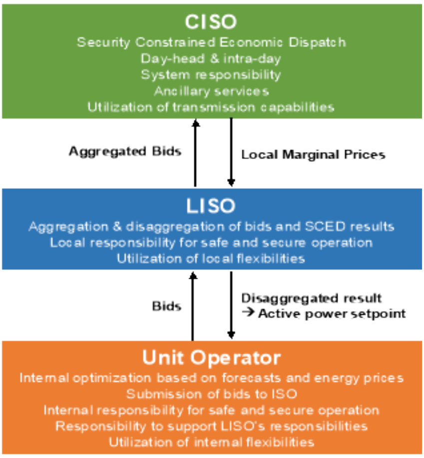
Agents in the Web-of-Cells system

- Each energy cell has an energy cell management. It is responsible for control, regulation, optimization, forecasting, error handling, and communication
- Decision-making entity: unit or system operator
- Unit operator: Responsible for everything that happens within an end-user energy cell as well as interaction with the superordinate energy cell
- ISO: Responsible integrated operation of energy grids as well as energy markets
- Local ISO: Responsible for safe and secure operation within the Energy Cell at distribution network level, acquisition of all relevant data from the energy cell and subordinate energy cells
- Central ISO: Operation of the central day-ahead and intra-day markets in coordination with LISOs and unit operators at transmission level, responsible for determining the operational status and active power setpoint for all units

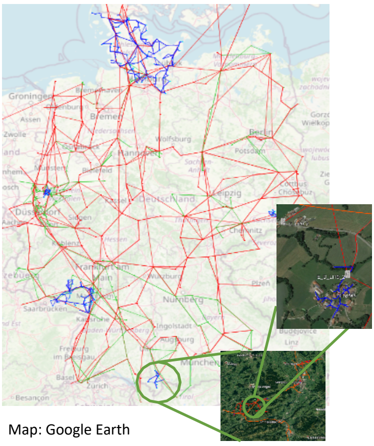


System and market architecture

- Day-ahead market: 1h intervals, 1 day ahead
- Intraday market: real-time, max. 15min intervals for quickly response to changing conditions possible
- Role model: ISOs in the United States
- Each energy cell is solely responsible for its own operation
- Information exchange is greatly reduced without compromising information quality
- Data handling becomes manageable despite large amount of system participants
- Massive parallel computation allows solving the overall optimization problem fast enough for real-time market operation
- All technical and operational limits are considered during market-clearing itself, creating an inherently congestion-free unit dispatch
- Local Marginal Pricing on Level C leads to transparent, non-discriminatory utilization of flexibility
- Harmful arbitrage behavior is impossible since the stages of the market-clearing are integrative rather than successive

Scenario data for 2050

- "Integrated Energy Transition" scenario from dena study that focuses on 100 % RES (2018)
- Strong focus on electrification, thus elevated grid utilization prevalent
- Regionalization of national targe figures is based on regional statistical and demographic information



Map: Google Earth

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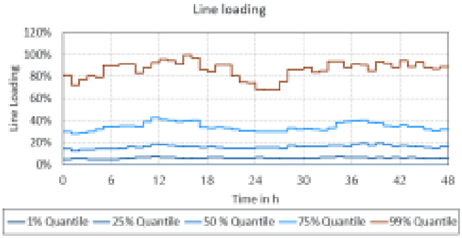
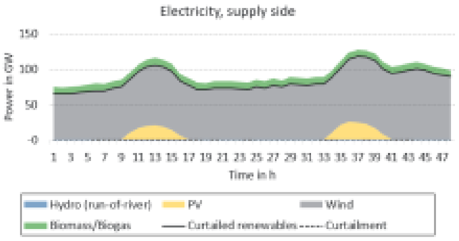
Grid and Technology Models

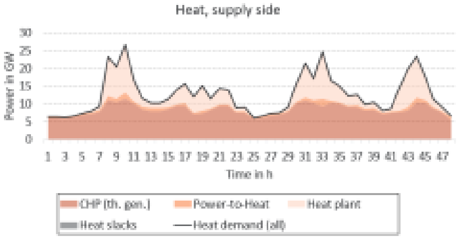
- Electrical grid: nationwide and vertically complete, reinforced to accommodate 160 GW peak load safely
  → Entire 220/380 kV transmission grid
  → 5 representative 110 kV grids
  → Each 30 representative 20 kV and 0.4 kV grids
- Gas grid: German transmission grid
- District heating regions based on CHP plants and building sector heating data
- Extensive models for generation and consumer technologies of all energy sectors and forms
- Most important flexibilities: heat pumps, electric vehicles, batteries, backup conventional power plants



Proof of concept

- Market clearing solved in a central fashion to identify implausible scenario data or model equations.
- Decomposition of the market model can be made to clear the energy exchange locally in each cell
- Two exemparly days in January 2050 are presented





Conclusion

- Market design has proven to be a key issue
- Local Marginal Pricing effectively counteracts congestions and incentivizes local flexibility usage
- Prices remain reasonable even during low RES supply
- Cellular market design is resilient against harmful behavior
- Trading intervals are adequate for volatile generation
- Complexity of the system becomes manageable organizationally, technologically, and economically by decomposition and parallel computing
- Further investigations into real-time operation, ancillary services, insufficient flexibility or transmission capacity required