Market-Based Self-Organized Provision of Active Power and Ancillary Services
An Agent-Based Approach for Smart Distribution Grids

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Outline

(1) Why do we need dynamic aggregation concepts for energy balancing and grid stability?
   • Control challenges in smart distribution grid
   • Regulatory issues

(2) How would an agent-based coalition approach fit into the current energy system?
   • Trading and planning
   • Operating supply and demand

(3) How do we incorporate specific grid constraints?
   • Grid arbitrator concept
Control challenges in Smart Distribution Grids

- **Time to real time:** Guarantee reaction within given time boundaries when using distributed components for system stability issues.
- **Restructure:** Allow transparent integration, segregation and substitution of new components to the ICT-system.
- **Scale:** Integrate a huge amount of distributed power producers and consumers.
- **Aggregate:** Dynamically adapt aggregation forms like virtual power plants.
- **Rejuvenate:** Allow to relocate functions from older to new ICT components to maximize benefits from technological evolution.
- **Be robust:** Disseminate critical system functions to redundant and distributed ICT components.

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Control challenges in Smart Distribution Grids
Regulatory aspects

Energy trading

Management of grid capacity

System operator
Optimize distributed grid operation by extending existing energy markets to address grid issues.

**Grid aspects** should preferably be subject to trading activities on the markets, when market-based solutions can be found that prevent grid capacity and stability problems [BNetzA2011]

Regulatory aspects

Energy trading

Management of grid capacity

System operator

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Smart Nord: Distributed control & new energy markets
Simplified usecase: Components

Shiftable load will participate in active power coalition.

Grid agent will provide crucial information regarding current status of the grid and needed ancillary services.

Controllable inverters will participate in reactive power coalition and offer option for delivery.
Planning phase: Trading and configuration

1. Order book open for active power
2. Coalition setup, bidding, matching
3. Internal optimization
4. Required ancillary services
5. Product setup ancillary services
6. Coalition setup, bidding, matching
7. Configuration for ancillary services
8. Active power delivery
9. Optional reactive power delivery
Operating phase: Incidents & continuous planning

Incident types

1. Reactive power usage
2. Prognosis fault
3. Component is off grid
Operating phase: Incidents & continuous planning

Incident types
1. Reactive power usage
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Compensation strategies
1. Compensate on Intraday-market
2. Compensate directly with other coalitions
3. Compensate between components
4. Compensate by changing P/Q control

Time to delivery

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Crucial component: Grid Arbitrator

Estimation of the current state of the grid, need for ancillary services

Operational states are dependent on the complex interaction between all actors and the interconnecting power grid

• Measuring of nodal voltages
• Calculating nodal voltages
• Calculating line currents

\[ S_i = U_i \sum_{k=1}^{n} Y_{ik} U_k^* \]

\[ I_1 \sim I_l \]

Below max. thermal currents?

Within feasible voltage bands?

Minimal Redispatch?

...now what?

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Integrated Representation of Feasibility Constraints

Traditional: „absolute“ evaluation of a state‘s feasibility
• Estimation of an operational state → element-wise evaluation of its corresponding nodal voltages and line currents

Required: „relative“ representation of feasible state spaces
• Calculating a state’s distance to operational constraints

Idea: *precalculating the set of feasible operational states*
• As a set in $\mathbb{R}^{2n}$ (for any given network with $n$ nodes), *High-dimensional problem!*
Keeping an operational state within Feasibility Constraints

Minimal adjustment to a given operational state

- Available degrees of freedom correspond to flexible/controllable demand and supply
Keeping an operational state within Feasibility Constraints

Minimal adjustment to a given operational state

• Available degrees of freedom correspond to flexible/controllable demand and supply

Supply

PV
BHPP

V2G

Demand

Heat-Pump
Household Appliances

Constraints:
Feed-in tariff
Production costs
User process
Availability

Constraints:
(Dynamic) tariff
User process
Integrated Grid Usage Coordination

State Optimization

Identification of relevant Feasibility Constraints

Arbitrator

Operational State

Network Model

Adaptive Model Integration

Adaptive State Estimator

Constraints

\[ P_{\text{max}}, Q_{\text{max}}, \Delta P, \Delta Q \]

\[ P, Q, U, I \]

e.g. Smart Metering

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What we will do next

Real-time requirements:
• Specific requirements?
• How to bridge the gap to the automation area?

Coalition formation:
• Which approach fits both areas (active power products, ancillary services)?
• Continuous planning approach?

Architecture and automation standards:
• Interaction with existing automation standards for EMS and DMS?

Market design and ancillary services products:
• Market design and rules, product types?
• Integration of grid feasibility check?
• Balancing group management?
Thank you!

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