Day-ahead market coupling in an agent-based electricity market model

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Motivation

▪ Long record of energy system models (ESM) (Gilliland, 1975)
▪ Growing complexity leading to new challenges to modelers (Pfenninger et al., 2014)
▪ Challenging to account for highest GHG reduction targets in current ESM (Pye et al., 2021)

▪ Agent-based modelling (ABM) is a promising approach:
  ▪ incorporating the actors‘ perspective (e.g. Nitsch et al., 2021)
  ▪ representation of heterogenous actors (e.g. Kraan et al., 2018)
  ▪ real-world examples relatively cheap in terms of computational cost (e.g. Hansen et al., 2019)

▪ Therefore, we apply the ABM AMIRIS to simulate electricity markets
▪ Our main research interest:
  ▪ integration of renewable energies & flexibility options in electricity systems
  ▪ analysis of market effects caused by policy and renumeration schemes
Project VERMEER
Security of supply in Germany and Central Europe during extreme weather events

Investigation of flexibility of cross-border electricity trading during extreme weather events considering dynamic Net Transfer Capacities (NTC)

Funded by BMWi (03EI1010A)
Project partners:
  KIT Karlsruhe (https://www.iip.kit.edu)
  DLR Stuttgart (https://www.dlr.de/ve)
AMIRIS
Agent-based Market model for the Investigation of Renewable and Integrated energy Systems

Model
- Electricity market simulation
- To be Open Source in Q4/2021

Agents
- Conventional Plants
- Renewable Plants
- Traders
- Flexibilities
- Markets
- Policy
- Forecasting

Calculates
- Electricity prices
- Plant dispatch
- Market values
- Emissions
- System costs
Geographic scope of AMIRIS

Currently:
- German market model
- Imports & exports: predetermined timeseries

Goal:
- Modell German and neighboring markets
- Imports & exports: Modelled via market coupling
Coupling markets in AMIRIS

Concept
- Introducing a new agent type *MarketCoupling*
- Participating day-ahead markets are connected to the *MarketCoupling* agent

Procedure
1. Day-ahead market agent collects bids & asks of its associated traders
2. Information together with Net Transfer Capacities (NTC) is sent to *MarketCoupling* agent
3. Market coupling is carried out ensuring NTCs are met
4. Updated (coupled) price is sent back to traders via their local day-ahead market agents
Detailed description of market coupling

- Identify potential candidates consisting of two markets
- Finding best candidates for coupling
- Decreasing price difference by smallest possible shift of demand from one market to other
- Re-evaluation of best candidates for coupling

- Termination when price differences cannot be minimized anymore, e.g.:
  a) price differences are zero, or
  b) all NTC are used

- Solution considered as global optimum
Case study

- Demonstration of implementation using 3 and 4 markets

- Different levels of NTCs (up to unlimited capacity)

- Investigation of:
  - electricity prices
  - awarded power

- Weekly plots of hourly resolution
Results: Case study of three markets

1 week at hourly resolution
Results: Case study of three markets – unlimited NTC

![Network Diagram](image1)

- **NTC: unlimited**

![Graphs](image2)

- **Awarded Power**
  - 1 week at hourly resolution

- **Price**
  - 1 week at hourly resolution

- **Results:** Case study of three markets – unlimited NTC
Results: Case study of four markets

- **NTC: 13 GW**
- **NTC: unlimited**

**Price**

1 week at hourly resolution

**Awarded Power**

1 week at hourly resolution
Results: From zero to unlimited NTC

Price

Awarded Power

System Cost

No coupling
Increasing NTC
Unlimited coupling
Conclusion

- Investigation of electricity markets using AMIRIS
- Introduction of MarketCoupling agent in AMIRIS allowing to extend geographic scope
- Implementation of Java based, incremental, and dynamic solving algorithm minimizing price differences
- Accounting for hourly Net Transfer Capacities as constraints to optimization
- Case study shows promising results, finding global optimum reliably

Discussion & Outlook

- Heuristic-based algorithm
- Consideration of domain specific properties (e.g. price steps due to merit order, minimum shift size)
- Full-scale deployment in real-world electricity market scenarios
- Further performance improvements of algorithm

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References


