Analayzing Effective Competition In Energy Market Using Multi Agent Modelling

Hamid Aghaie
Researcher at Energy Department, AIT Austrian Institute of Technology
PhD Student in EEG Group, TU Wien

Supervisors
Prof. Reinhard Haas, Dr. Peter Palensky
Introduction: Changing Landscape

Increasing the share of Intermittent Renewables in the electricity market
Problem Statement

- Electricity produced by renewables:
  1) Highly fluctuating and intermittent
Problem Statement

- Electricity produced by renewables:
  2) Less utilization of conventional generators
Problem Statement

- Electricity produced by renewables:
  3) Lower market price
Problem Statement

- 1, 2, 3 brings:
  - Less utilization and less revenue for conventional generators
  - Less incentive to investment in conventional generators
  - Less reliable backup in the market

- **Supply Security Problem**

- Missing Money ~ Resource Adequacy ~ Revenue Sufficiency
- ISO needs a way to repay this “missing money” to keep enough generation on hand
- **Research Question:**
  - How an effective competition in energy market can solve this problem?
Market Structure: Effective Competition

- Effective competition in new market design
  4 elements

1) Efficient Scarcity Prices

NOW
- Scarcity situation occurs rarely
- Price cap

To Do
- Increase the frequency and duration of scarcity situations
- High price caps
- e.g. ERCOT,
  - maintain energy-only market (2012)
  - $4500 per MWh in 2012 to $9000 per MWh in 2015
Market Structure: Effective Competition

- 2) Active demand side participation
  - Add flexibility to the market
  - e.g. Interruptible loads
  - e.g. PJM market, 2000 MW in 2007 to 16000 MW in 2015 (10% of total capacity cleared in capacity auctions)

- 3) Utilization of storage facilities
  - Add more flexibility to the market

- 4) Optimized guaranteed policies
  - Reduce the investment risk
  - e.g. renewables support policies, introducing price caps
Methodology

- Multi-Agent Systems (MAS)
  - Agent: an entity that acts upon the environment it inhabits
    - rationality
    - Autonomy
    - Proactiveness
    - Reactivity

- Game Theory (GT): analyze the interplay between parties that may have similar, opposed, or mixed interests

- Difference between GT and MAS: Strategic Decision Making

- Hybrid Model (MAS + GT)
Methodology: Market Model

- **Generators**
  - Conventional
  - Renewables

- **Market (ISO)**
- **Suppliers**
- **Wholesale Customer**
- **Retailer (Market Customers)**
- **End Users**
  - Residential
  - Industrial

Diagram:
- C: Conventional
- R: Renewables
- Other symbols represent various market and system components.
Methodology

- Agents' strategies (actions): \{Bidding price, Bidding quantity\}
- Agent's goal: maximize its own individual surplus

Strategy selection: $\epsilon$-Greedy

$P$ (Probability of selection) = \[
\begin{cases} 
1 - \epsilon + \frac{\epsilon}{n} & \text{Action with best payoff} \\
\frac{\epsilon}{n} & \text{Other actions}
\end{cases}
\]
Methodology

- **Reward Function**
  \[
  R_{a_i} = MPC - q_{a_i} \cdot c_{a_i} \\
  R_{a_i} = q_{a_i} \cdot d_{a_i} - MPC
  \]
  for Generator Agent
  for Consumer Agent

- **MPC**: Market Clearing Price
- **\(q_{a_i}\)**: Bidding Quantity
- **\(c_{a_i}, d_{a_i}\)**: Bidding Prices

- **Update Q-values**:
  \[
  Q_{a_i}^{new} = (1 - \alpha) \cdot Q_{a_i}^{old} + \alpha \cdot R_{a_i}
  \]
  \(\alpha\): Learning Parameter
Conclusion

- **Purpose:**
  - Solve supply security problem using characteristics of market competition instead of administratively determined capacity requirements
- **Effective Competition:**
  - Efficient Scarcity Prices
  - Active Demand Side Participation
  - Storage Facilities
  - Optimized Guaranteed Policies
- **Method:**
  - Multi Agent Modeling
    - Adaptive learning
    - Strategic decision making
Thank You!