MODEL DESIGN FOR THE ANALYSIS OF MARKET-BASED REDISPATCH –
USING DEEP REINFORCEMENT LEARNING
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Viktor Zobernig, July 2023

Redispatch

Change of load and generation schedules aiming to change load flows

"Redispatch refers to the short-term modification of generation and load schedules to avoid network congestion. ***It is a congestion management measure****.*

Power feed-in is increased on one side of the congestion and decreased on the other. *This creates a flow of power in the opposite direction to the bottleneck and relieves the bottleneck."*
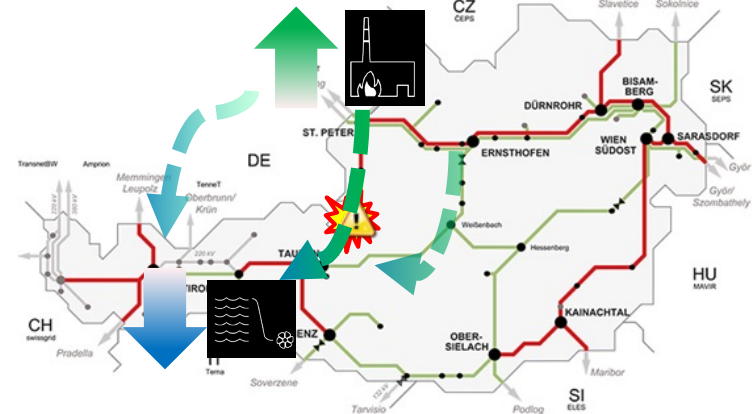
Growing need and costs for redispatch

- Increasing need and costs for redispatch in Europe (Due to a growing share of renewables, the progressive energy market integration and a slow pace in grid expansion, ACER Market monitoring report, 2020.)

- CO_2 reduction by the growing share of renewables is limited due to a resulting increased need for redispatch (A case study from Spain estimated that 10% of CO_2 emissions of the energy consumption are caused by redispatch, D. Dav́ı-Arderius and T. Schittekatte, 2023.)

- High potential of reducing costs and CO_2 emissions by including more flexibility providers (Curtailment of renewables can be reduced up to 76% by demand response in European countries, T. Müller and D. Möst., 2018.)

- Need for proper incentives to increase participation of flexibility providers in redispatch schemes (A case study from the UK estimated cost savings of 8-21% by 2050 through competitive procurement, K. Anaya and M. Pollitt. A, 2022.)
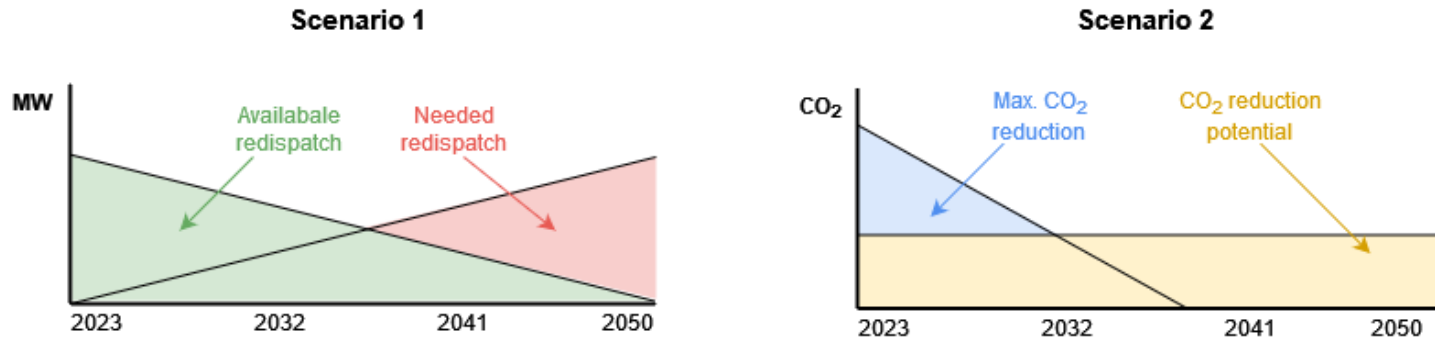

Figure 1: Simplified illustration of two potential scenarios if there is no change in redispatch procurement. Adapted from the German study „Redispatch 3.0".

Model limitations to assess market impact

- Problem for market-based procurement is the risk of gaming
- A suitable market design must be developed together with accompanying countermeasures

Currently applied models used to address this issue are limited by:

- Excluding important sources of risks
- Giving information that is not available in reality
- Increasing model complexity

Using an agent-based model of the electricity market, representing market participants using a deep reinforcement learning (DRL) algorithm

1. Observe any form of strategic behavior in electricity markets
2. Use more realistic model assumptions
3. Analyze more complex model environments

Model framework: Two-staged market

Analyze strategic bidding behavior in a two-staged market design:

1st Stage: Day-ahead market based on zonal market clearing

2nd Stage: Redispatch market to solve potential Congestions arising from the day-ahead market

Objective: Agents should learn to increase their rewards through scrutinizing the opportunities between these markets (i.e., "inc-dec gaming")

→ Proofing the applicability of using DRL to analyze strategic bidding

→ **Goal:** Introduce different market designs and/or countermeasures to decrease the incentive of gaming
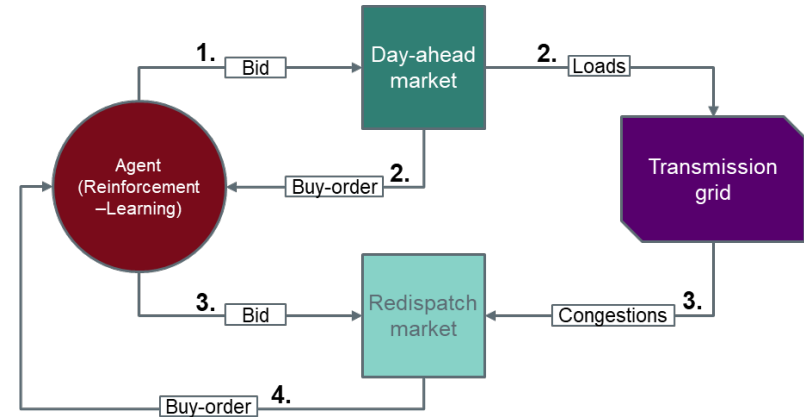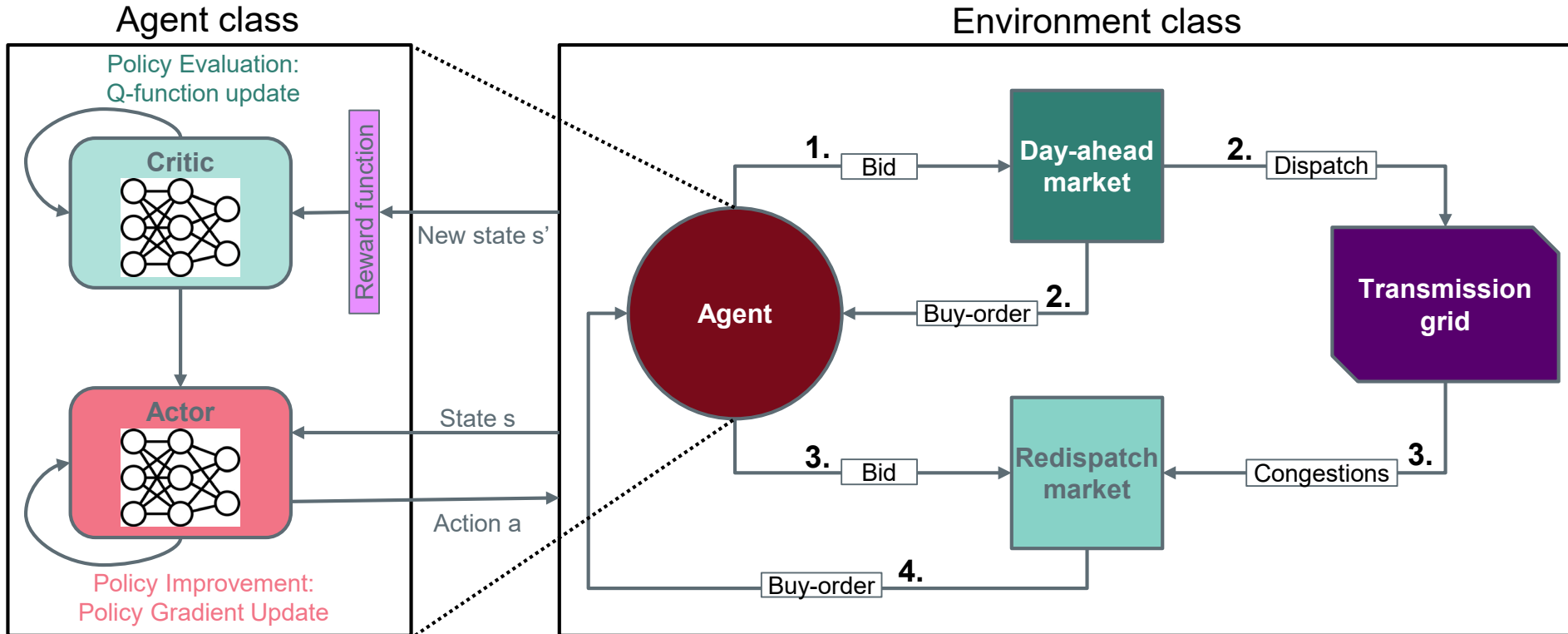

Figure 2: Simplified illustration of the ABM, including day-ahead market, redispatch market, grid model and reinforcement learning agents

Model framework: Learning agents

Figure 3: Simplified illustration of the market environment and the deep reinforcement learning algorithm.

DRL-Agent: Inc-Dec gaming within a monopoly

Profits with **cost-based** redispatch

Profits with **market-based** redispatch
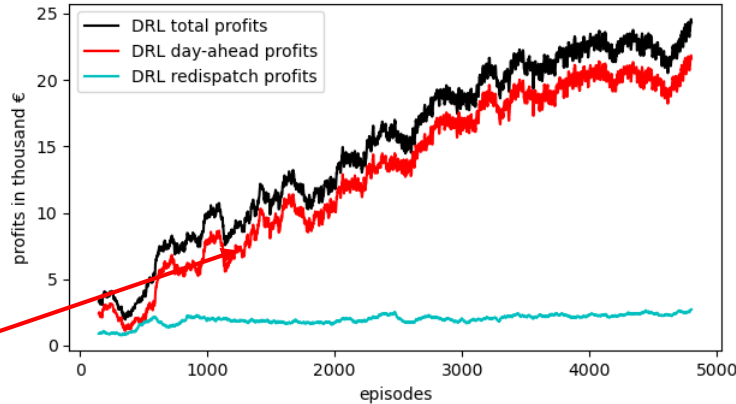
Majority of profits are made on the day-ahead market (market prices are low due to high competition and no incentive to offer redispatch)
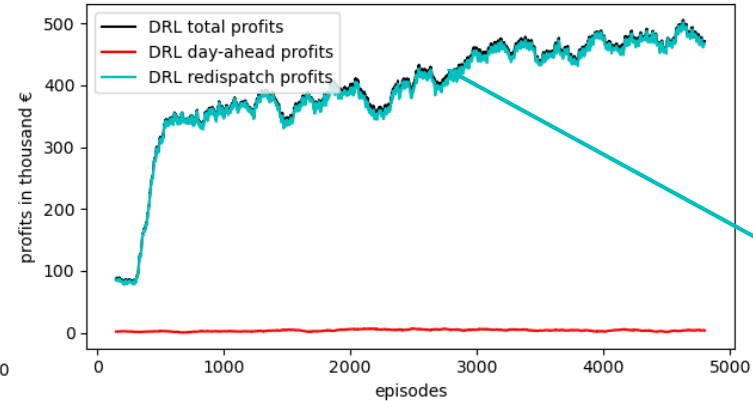
Majority of profits are made on the redispatch market. (Agents engage in gaming strategies by further increasing congestion)

We can demonstrate a change in the agents' bidding behavior due to the introduced market design under a monopoly → Enables us to **develop and verify appropriate mitigation measures**
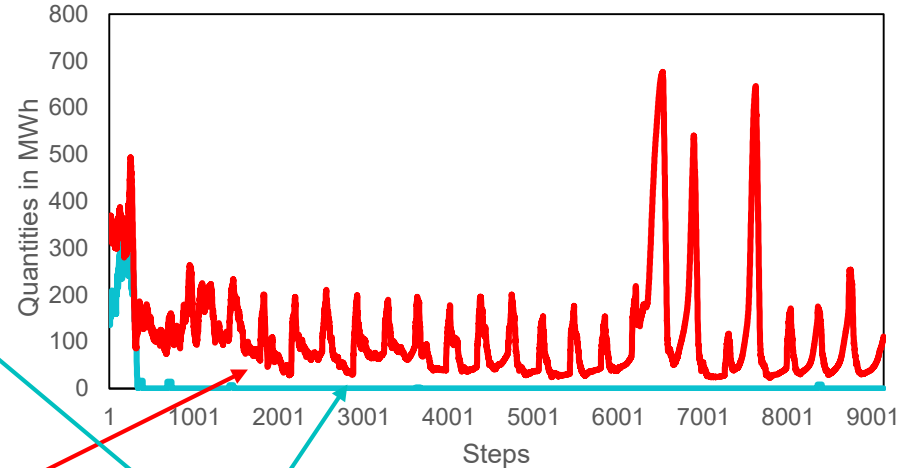
DRL-Agent: Inc-Dec gaming day-ahead strategy

Price Bids for Day-ahead Market

Quantity for Day-ahead Market
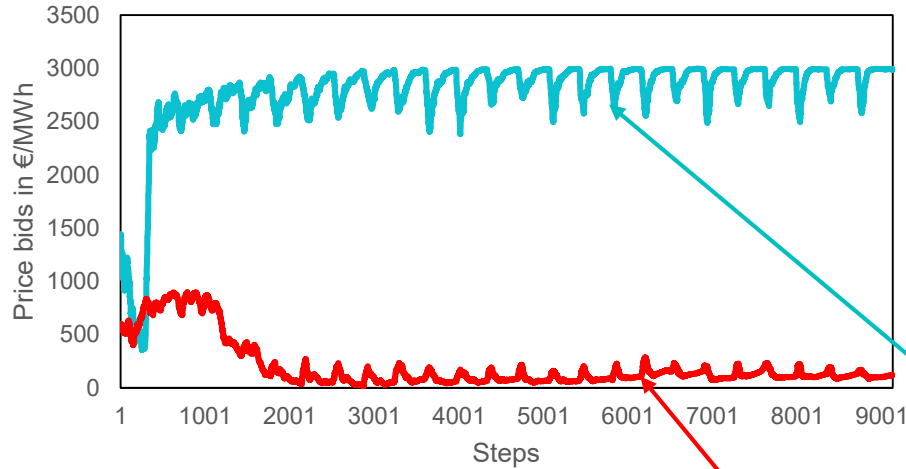
Price Bid with Market-based Redispatch
Price Bid with Cost-based Redispatch

Quantity Bid with Market-based Redispatch
Quantity Bid with Cost-based Redispatch

With **cost-based** redispatch:
1) DRL-Agent tries to bid prices **near the marginal bidder**
2) DRL-Agent sells **max. quantity** on the day-ahead market

With **market-based** redispatch:
1) DRL-Agent **bid prices equal to the expected prices for redispatch**
2) DRL-Agent **bids less quantity to increase congestion**

Market-based redispatch = "bad"?

Why market-based redispatch remuneration if it leads to gaming?

- Risk of gaming only if the actor poses market power

- Markets potentially incentivize further flexibility providers (less monopoly)

- Including demand response enables to include more renewables

- Increase transparency (Cost-based payments are not easy to evaluate and often untransparent)

- **Overall socio-economic cost can get reduced** (Note: cost-based compensation includes high administrative cost)
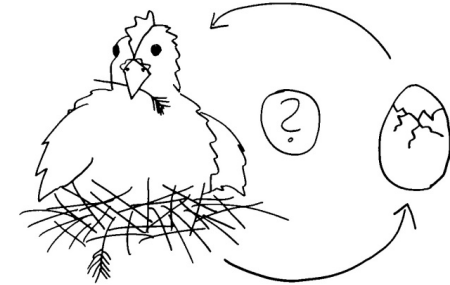

Figure 4: "Chicken and egg problem" – Fear of implementing a market, because of view participants; Without a market there is no incentive to participate;

Answer: "Yes/No, its complicated but if implemented right definitely!"

The next step is to include different market designs and countermeasures applied in reality and suggested by the literature to assess the impact on social welfare!

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