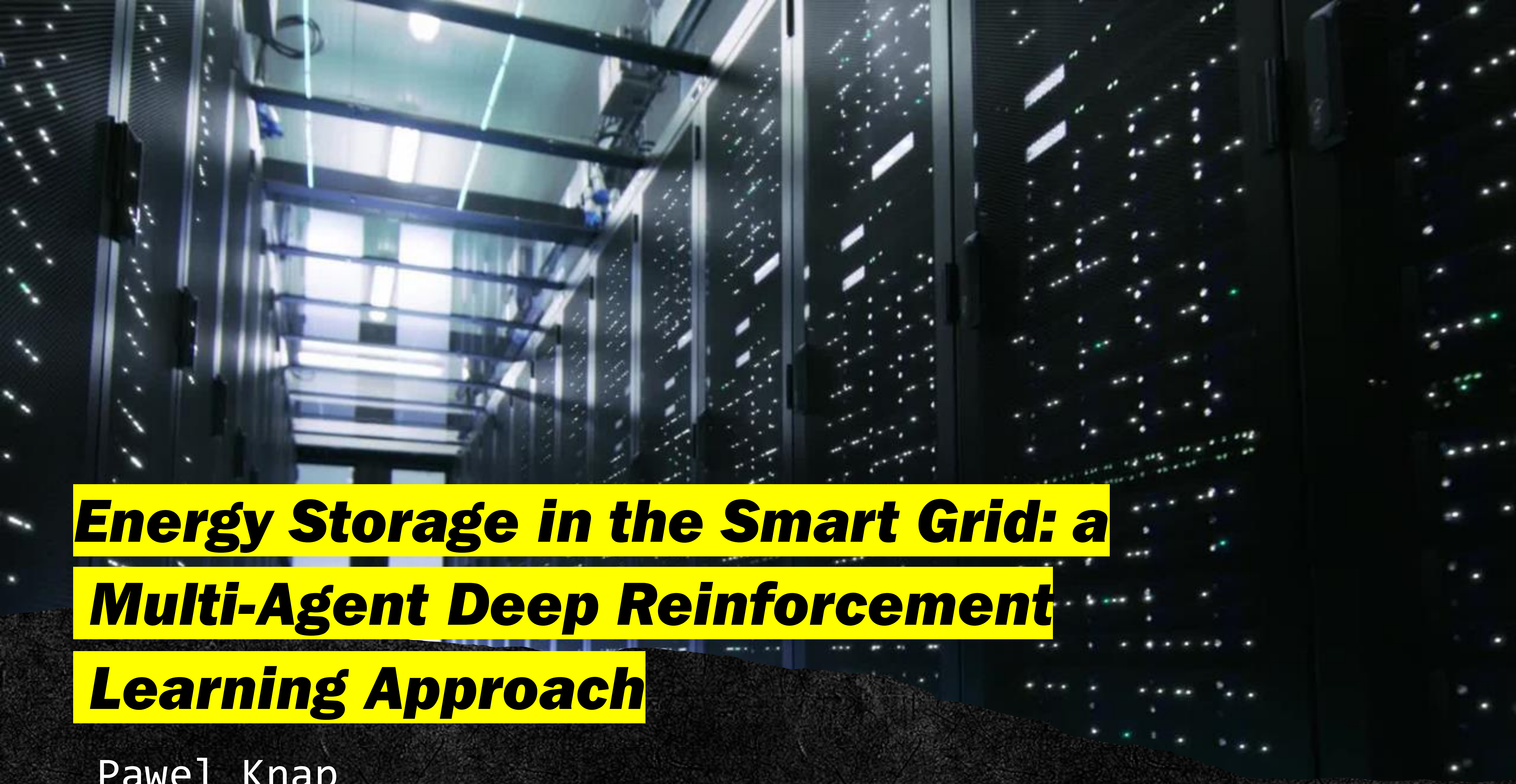

Energy Storage in the Smart Grid: a Multi-Agent Deep Reinforcement Learning Approach

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Smart Grid

- Inclusion of many small renewable energy sources and storage systems
- Decreases costs and carbon footprint
- Advanced metering infrastructure and load control
- Improves efficiency and reliability
- Introduction of variable tariffs - possibly adversarial for consumers

In-house energy storage

- Solution to variable tariff issues
- Currently used as UPSs or storage for excess solar energy
- Lack of control schemes for small battery systems
- I propose novel RL-based control scheme

Project dichotomy

Single agent simulation

- Objectives: achieving biggest savings in different configurations (with/without PV)

Multi-Agent System simulation

- Objectives: investigating influence of my system on other houses with/without it and on energy grid

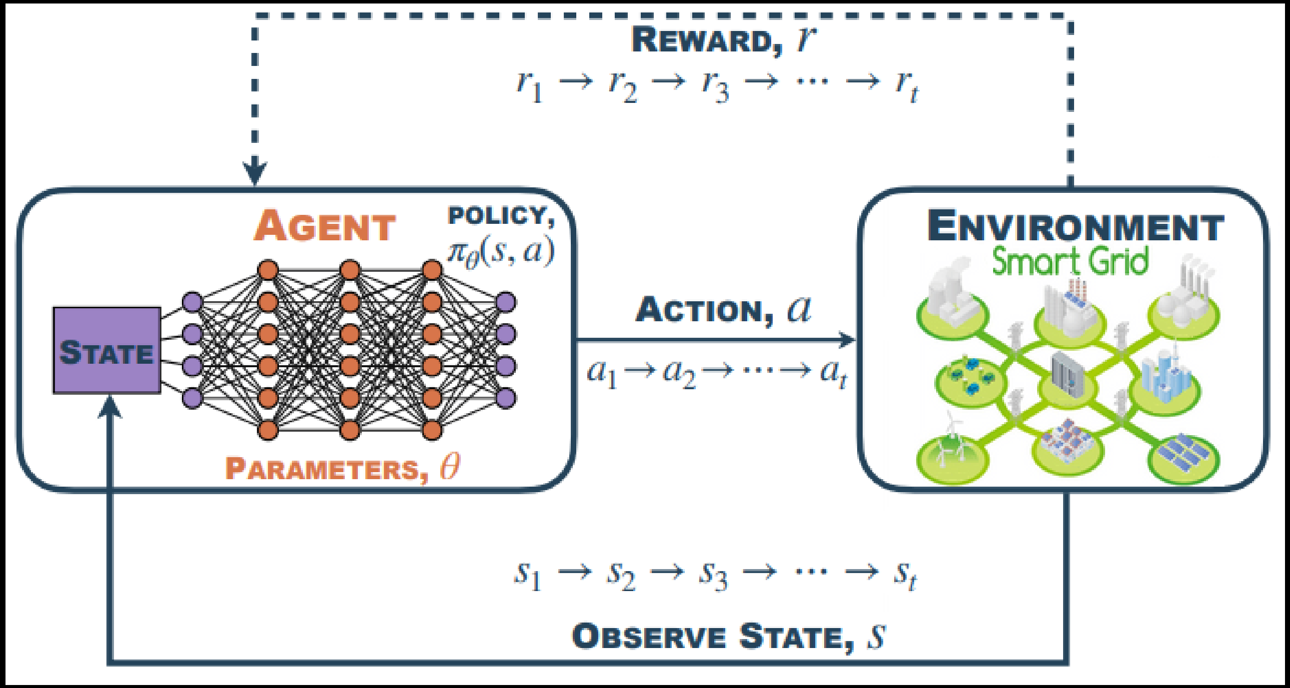
Single agent simulation

- Two baselines

a. Rule-based approach

b. Q learning

- and Deep Q Learning (DQL) agent



Actions

States

	A_1	A_2	...	A_M
S_1	$Q(S_1, A_1)$	$Q(S_1, A_2)$		$Q(S_1, A_M)$
S_2	$Q(S_2, A_1)$	$Q(S_2, A_2)$		$Q(S_2, A_M)$
$\vdots$			$\ddots$	$\vdots$
S_N	$Q(S_N, A_1)$	$Q(S_N, A_2)$	...	$Q(S_N, A_M)$

Single agent simulation

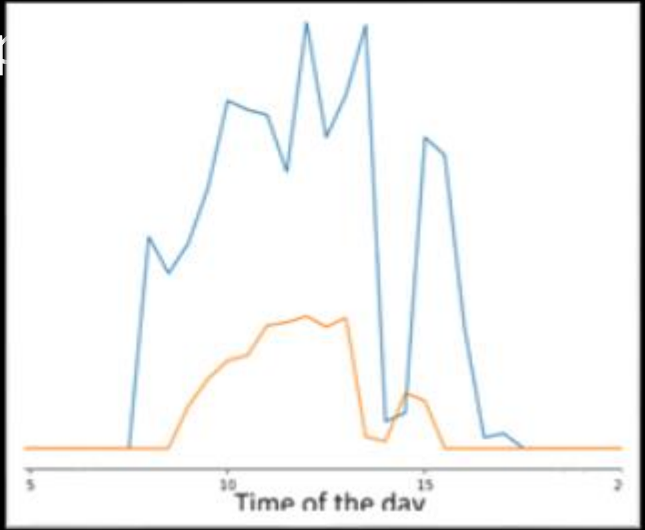
- Three generation of DQL:

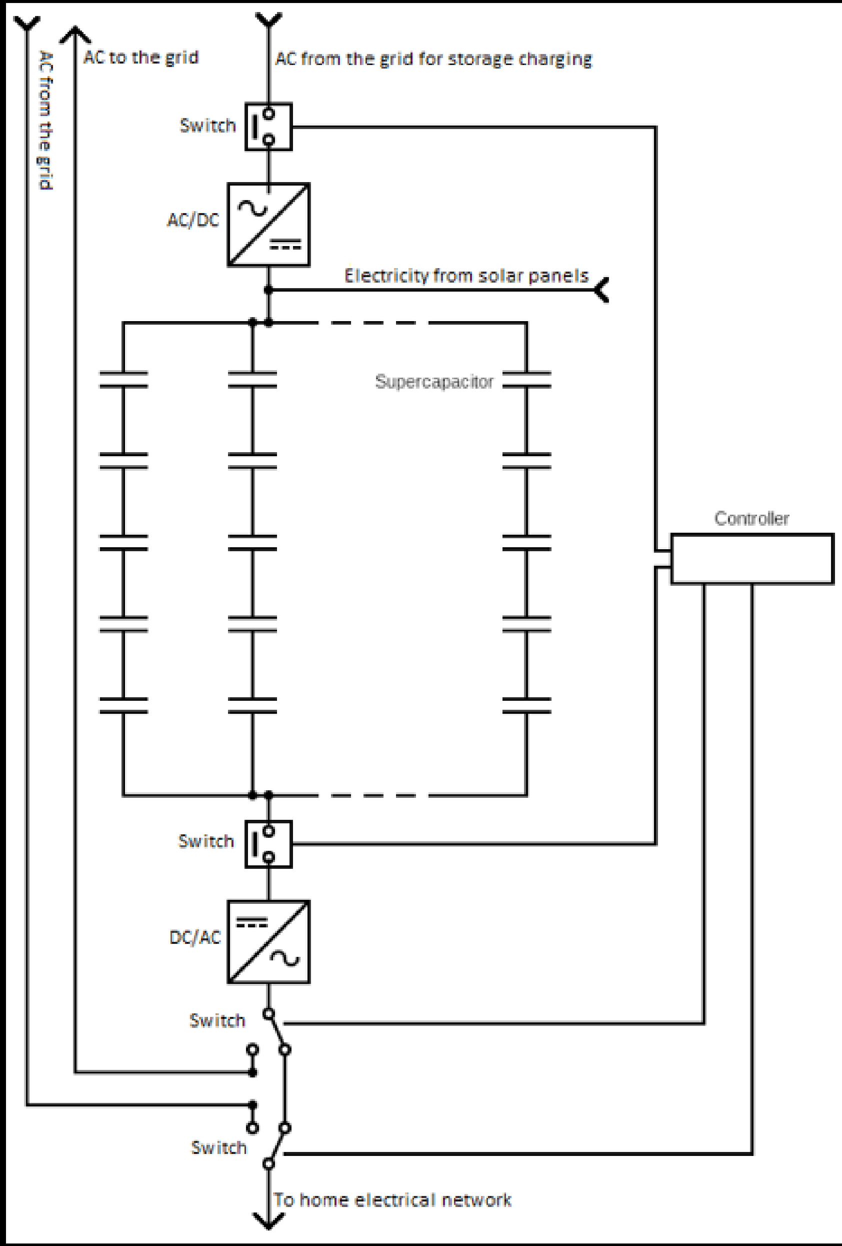
i. Three actions available: buy, use, wait

ii. Four actions available: buy, use, wait, sell

iii. Simulation of solar energy generation added

- Evaluation of ROI and project practical imp





Single agent simulation results

- Variable tariffs lead to significant (up to 35.7%) annual electricity bill reductions for most households (98%), as compared to flat tariff.
- My storage system offers substantial savings (average of 20.91% as compared to variable tariff) for all households including these negatively affected by tariff change.
- Combining my storage system with PV results in increased savings.
- In single-agent simulations with PV, immediate self-use, surplus storage, and excess energy sales prove the most efficient scheme
- Higher total yearly household consumption reduces system savings.
- Savings rise with higher battery capacity, plateauing around 4kWh.
- DQL agent rarely uses high currents, thus increasing battery lifetime.

Multi-Agent System (MAS) simulation

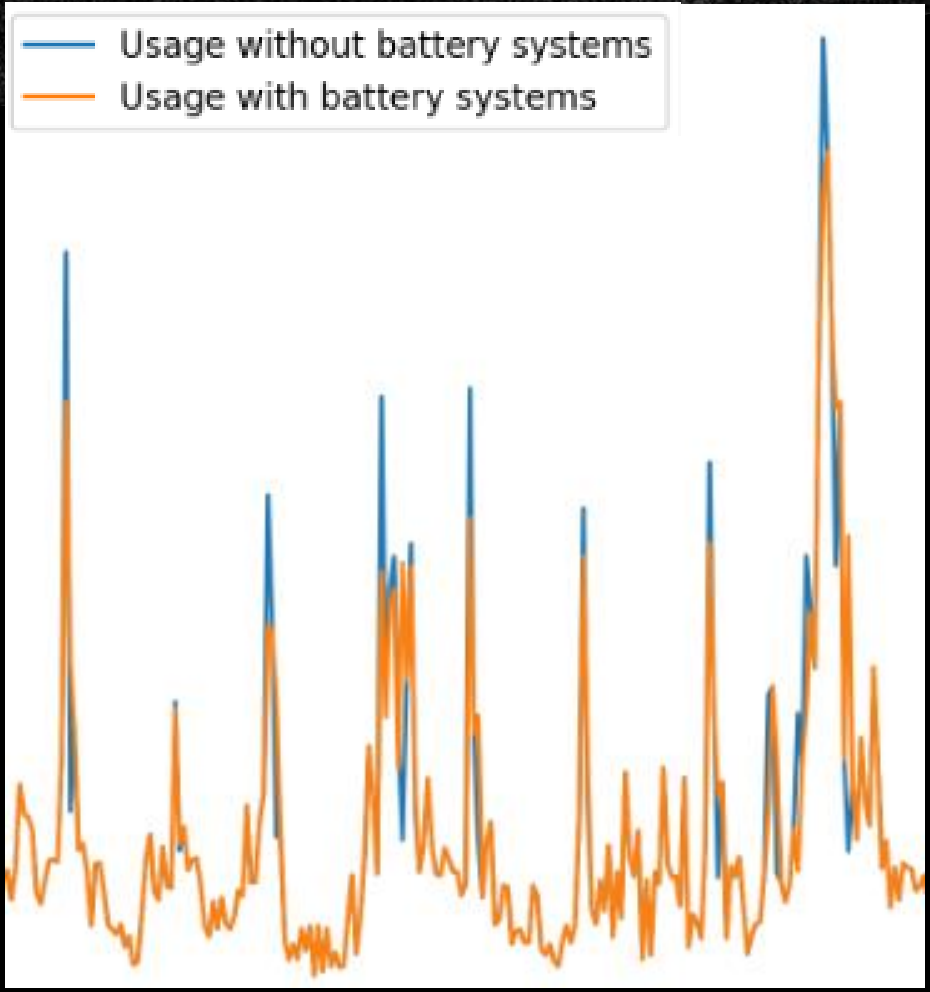
Testing different price-demand functions

- Linear
- Exponential
- Logarithmic

Investigating the mutual impact of agents

Different configurations of prosumers and consumers

MAS simulation results



- In MAS with PV, the direct storage and surplus sale approach proves to be the most efficient.
- Steep price-demand functions in MAS lead to higher savings, yet variable tariff pattern aligns more with logarithmic function.
- Households in MAS benefits from widespread adoption of my storage system, but even non-adopters benefit from its presence.
- My storage system eases stress on the power grid by leveling demand peaks.

Summary and Conclusions

- Novel control scheme for small in-house energy storage
- Significant savings and acceptable ROI time – especially when combined with PV
- Power grid stress reduction and better PV incorporation
- Removes inconveniences and drawbacks of the variable tariff for consumers thus improves social approval for smart grid
- System is beneficial for consumers, suppliers and other electricity network users