Optimization in energy communities

Reinforcement Learning and mathematical optimization model

Syed Ali Mashood Naqvi and Yannik Weber

Technology Arts Sciences TH Köln

Intelligent use of energy is one of the keys to success for an energy revolution. With growing use of renewable energy sources and growing tariffs for electricity production, the need for optimization in small scale grids is omnipresent. Two possible models to optimize the usage and production of energy in small communities are presented on this poster.

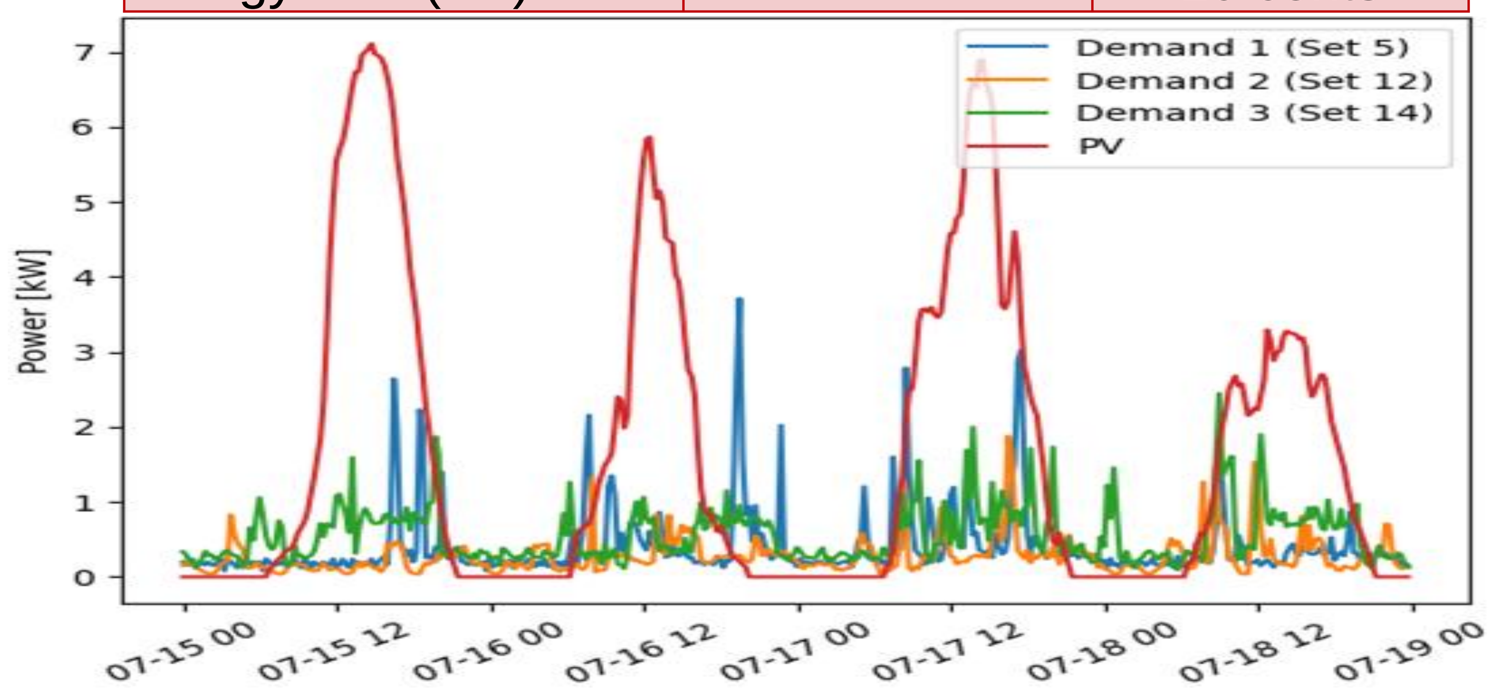
INTRODUCTION – ABOUT THE PROJECT

Distributed electricity generation or optimal power flow problems can be solved by several methods. Some of them are using conventional mathematical models, others are using Machine Learning techniques including DNN and RL. In this project, a mathematical model is compared with a Reinforcement Learning approach. Therefore, two models were built, run and evaluated on the same set of data.

ISSUE AND OBJECTIVE

- Growth of Renewable Energy requires decentralization of the energy systems.
- The primary objective is the optimization of the distribution of electricity to minimize the cost of energy production.
- Two approaches were adopted for the grid optimization. Reinforcement Learning and a Mathematical Optimization model.
- The main purpose of these approaches is the cost reduction for energy production and distribution.
- The two models were used on the same input-data.
- The three sources are PV-generator, battery storage and grid.
- The following parameters were adopted for the two models:

Parameter	Reinforcement Learning	Mathematical optimization
Grid capacity	15 kWh	grid model dependent
Storage capacity	10 kWh	10 kWh
Max. charging power	/	5 kW
Initial storage charge	0 kWh	0 kWh
Energy cost (grid)	40 cents	40 cents
Energy cost (storage)	15 cents	15 cents
Energy cost (PV)	10 cents	10 cents



METHODOLOGY

Reinforcement Learning

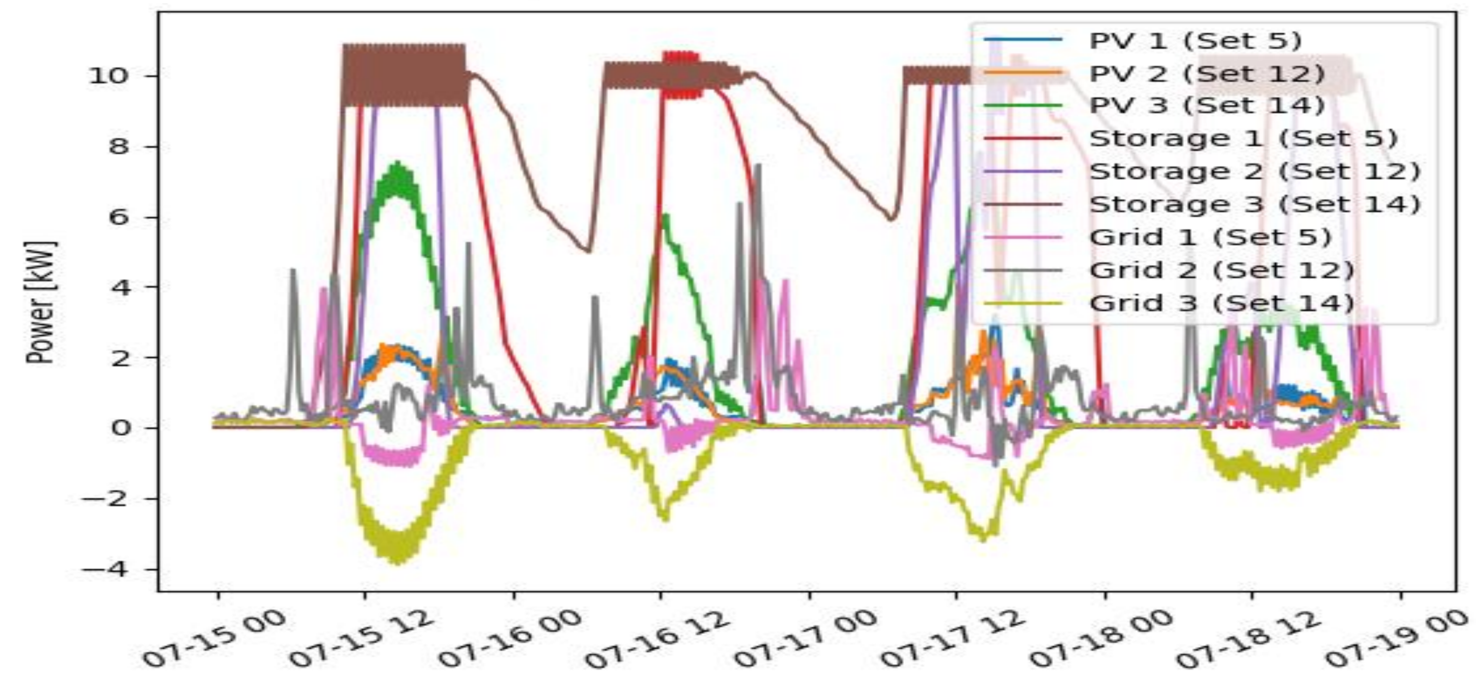
Reinforcement Learning is accomplished through the trial-and-error method, in which the agent learns by performing predefined actions and accumulating rewards. A custom environment is designed in the given approach, allowing the agent to take electricity from the sources given, to optimize the electricity distribution in the given scenario. The observation space is the given load that it had to cover. The agent interacts with the environment and learns to take the best possible action based on its experience under the given conditions.

Mathematical optimization model

In the mathematical optimization model the three houses are calculated in a connected grid and optimized simultaneously. For this a cost function is implemented as the objective, which considers the costs for energy used from PV-generation, storage and grid. Further several constraints were given regarding the input data as well as the storage and line parameters. Finally, the power or nodal balance is calculated as balance of energy taken from each source and the demand at each bus. The grid can be used as infinite energy source and is considered the most expensive one.

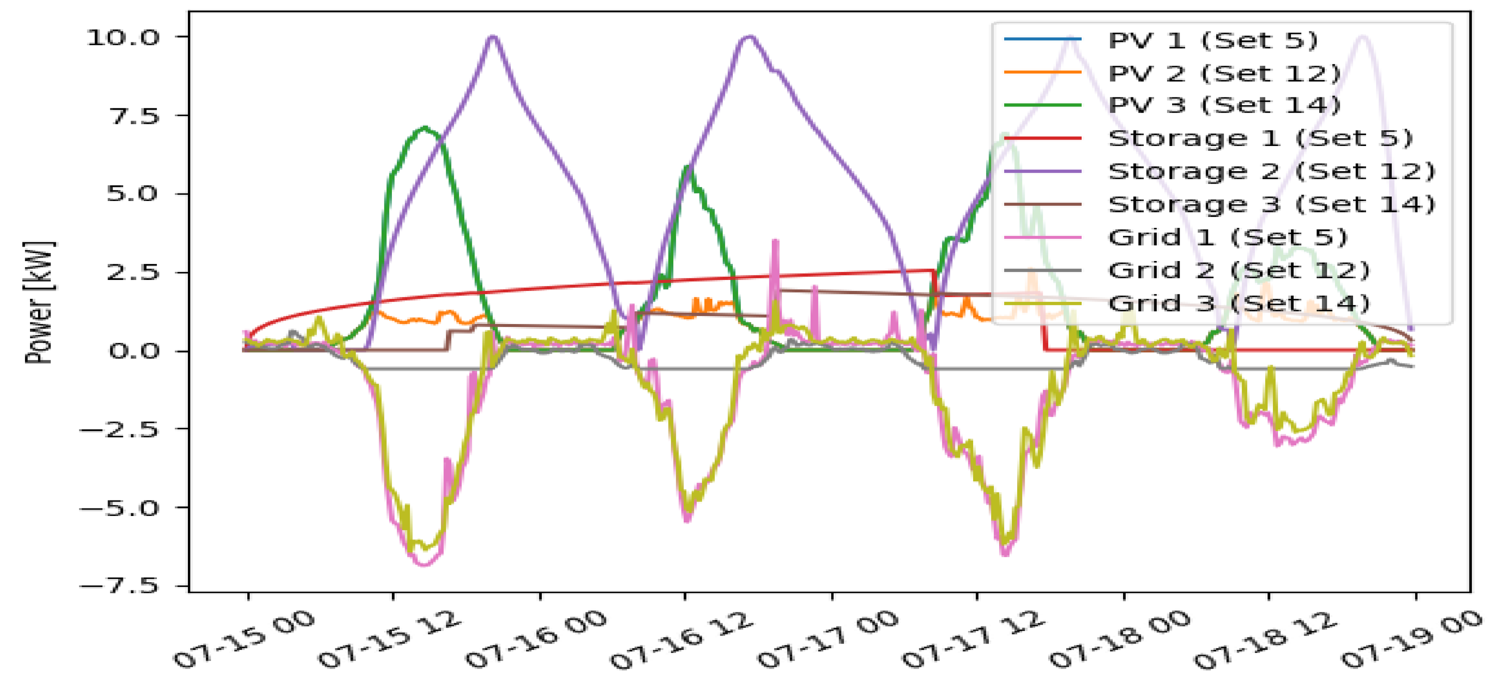
RESULTS

Reinforcement Learning



- The storages are charged and discharged within each cycle.
- Exportation to the grid is only seen with Set 14 noteworthy.
- Only one house at a time is optimized.
- Has a higher self-consumption rate.

Mathematical optimization model



- One storage is used regularly; a fraction is used of the other two.
- High exportation rate due to cost function not differentiating between energy taken from or put into the grid.
- Generator shut-down experienced at the second house.
- All houses are optimized in a small interrelated network.

DISCUSSION

- Both models are applicable for grid optimization with focus on cost reduction for electricity usage.
- For the Reinforcement Learning model, it would be interesting to see the results for hyperparameters tuning, using Multi-agent Reinforcement Learning and implementing the Epsilon Greedy Method to a certain extent.
- The mathematical optimization model reduces the cost significantly when exporting energy into the main grid. One solution for this issue could be to use absolute values of energy taken from or exported to the grid. Another approach could be to split the variables for the grid energy into usage and exportation and only take the usage into account for the cost function.

CONCLUSION AND OUTLOOK

- The Reinforcement Learning model shows consistent results for single PV / storage combinations.
- The Reinforcement model is for single household optimization. It will be interesting to see for multi household optimization.
- Adaptation of the model using a Multi-Agent Reinforcement Learning model is recommended.
- The Mathematical model can be further expanded to optimize networks with different PV / storage combinations.
- An implementation to prevent a Generator Shut-down can be interesting for this model.
- Interaction with the grid should be investigated to improve self-consumption.

Contact: Syed Ali Mashood Naqvi (B.Sc)
syed_ali_mashood_naqvi.naqvi@smail.th-koeln.de
Cologne University of Applied Sciences (TH Köln)

Contact: Yannik Weber (B.Eng)
yannik.weber@smail.th-koeln.de
Cologne University of Applied Sciences (TH Köln)

cire Cologne Institute for Renewable Energy