FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE
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Improving Microgrid Autonomy with Reinforcement Learning Electric Vehicle (Dis)Charging Algorithms

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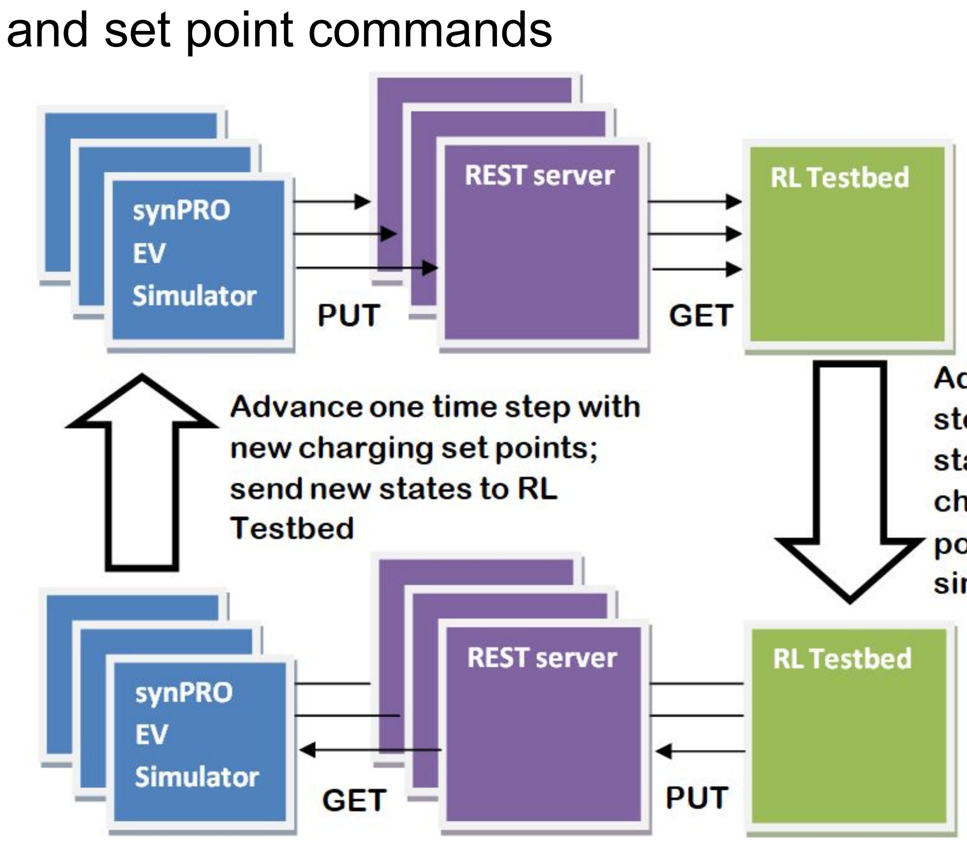
INTRODUCTION

The flexibility of microgrid energy dispatch can be improved by using EVs as storage devices that can consume intermittent renewable energy generation surpluses and then re-inject this energy at a later time. We apply reinforcement learning (RL) based methods to the distributed, EV-enabled load balancing problem inherent to this strategy. We observe the performance of EV charging/discharging controllers that use RL to decide its power flow set-point for every minute of its EV's scheduled charging/discharging session.

METHODOLOGY

- Microgrid load profiles were simulated with Fraunhofer's synPRO simulation tool developed in Python
- synPRO generates simulation traces of power systems components with a stochastic bottom-up approach, using real usage data and realistic models
- EV charging controller programmed in Python, runs concurrently with EV battery simulator running in synPRO; REST API used to exchange state information and set point commands



SYSTEM MODEL

- Energy community of five apartments with energy consumption habits typical of their subtype
- Four electric vehicles of differing models, and thus different energy needs and charging/discharging characteristics
- Community serviced by combination of main electrical distribution system and local PV distributed energy resource
- PV generation output modelled after a real PV plant in Freiburg recorded in the year 2013; The PV signal was scaled to have a 15.85 kW peak generation capacity, which made its total generation over the entire year 20,000 kWh.
- Considered two scenarios for smart grid communications infrastructure
  - Case 1: Smart meters report minute-scale price signal to EV controllers
  - Case 2: Also have aggregator node to prevent surplus EV discharge

Type	Subtype	Peak kW	Annual kWh
PV	-	15.84	20,000
Apartment	Family (1 Child)	7.22	3,532
Apartment	Family (2 Children)	7.72	4,806
Apartment	1 Full Time Worker	5.07	1,766
Apartment	1 Full Time Worker	6.86	2,065
Apartment	2 Pensioners	5.86	2,848
EV	Tesla Model X P100D	22	2,340
EV	Opel Ampera	11	1,319
EV	Opel Ampera	11	849
EV	Renault Twizy	3.7	475

Reinforcement Learning Enabled EV (Dis)Charging

Markov Decision Process Perspective:

- The **environment** is the EV and power system, while the **agent** is the charging controller
- Every minute, the EV charger must update its charging set point; this update is considered the **action** that the agent is taking
- The **state** of the environment consists of the EV's SOC, time of day, time remaining in charging session, and EV's most recent PV energy allocation
- **Reward** is characterized as the net amount of local energy that the agent consumes as a consequence for the past minute's charging set point decision.

Reinforcement Learning Implementation:

- Used **Expected SARSA** reinforcement learning method, an off policy, model free, temporal difference (TD) based method
- Leveraged **value function approximation** techniques to handle multi-dimensional, continuous state-action space
- Enhanced performance with domain knowledge by designing an **action preference function** to prohibit invalid actions in certain states

RESULTS

Self Sufficiency Definition:

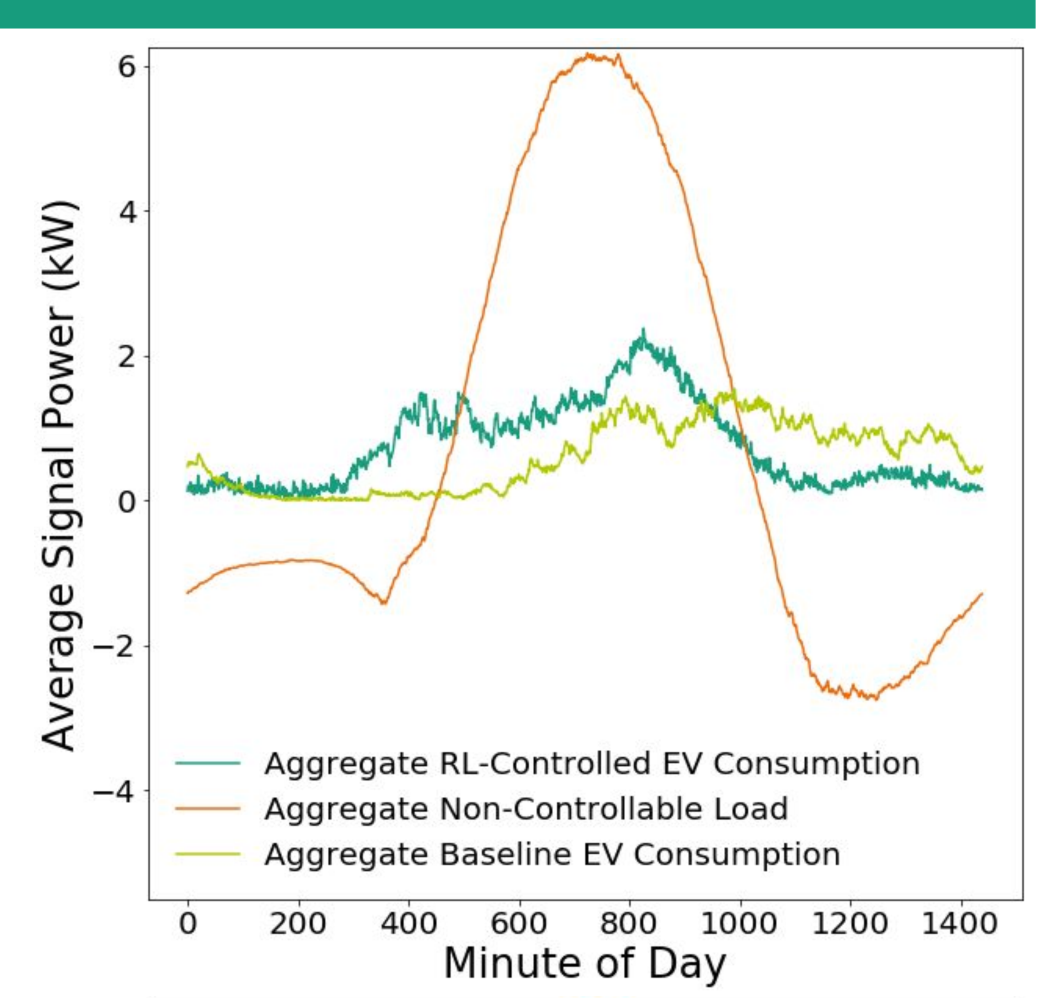
$$\frac{\textit{Local PV Energy Consumed}}{\textit{Total Energy Consumed}}$$

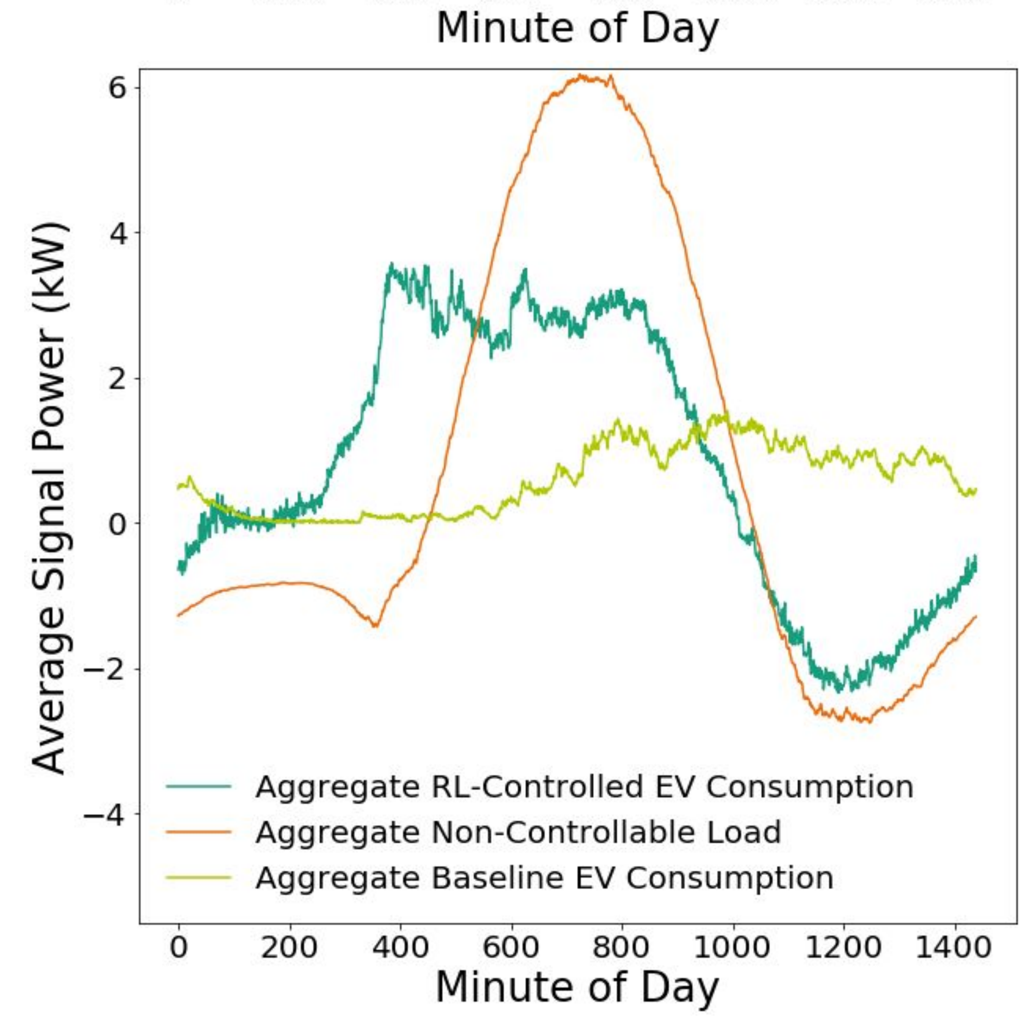
Mean Day Curve Definition:
A power curve where every data point represents the average power consumption at that point in time observed throughout the experiment

Experiment & Outcome
Trained agents on one year's worth of simulation data, then observed its performance on a new year's worth of data

Scenario 1 (charge only) increased overall self sufficiency from 28.4% to 34.8% (6.4% increase)

Scenario 2 (charge and discharge) increased overall self sufficiency from 28.4% to 45.1% (16.7% increase)





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