Proposal and registration for Master Thesiswork

Topic / Theme

- Training Prosumer Agents with Reinforcement Learning for Energy and Cost Optimization.

Introduction :

The increasing integration of solar photovoltaic (PV) systems and electric vehicles (EVs) into residential grids presents exciting opportunities for self-consumption and grid stability. However, optimizing energy flow between these components while considering dynamic pricing, varying solar generation, and user preferences remains a significant challenge. This research proposes one such approach using reinforcement learning (RL) algorithms to optimize self-consumption of generated PV and cost reduction in a prosumer household (a household that consumes from the grid as well as produces and feeds the excess photovoltaic energy back to the grid).

Literature review :

Existing studies explore grid-connected systems with PV and EVs, employing rule-based control, optimization algorithms, and machine learning techniques. Rule-based approaches often lack adaptability and may not capture complex dynamics. Optimization methods require accurate forecasts and can be computationally expensive. While machine learning approaches like supervised learning offer promising results, they often require large datasets and may not generalize well to unseen scenarios. RL offers a unique advantage in directly learning optimal control strategies through interaction with the environment, making it suitable for handling real-time decision making under uncertainty. By using reinforcement learning algorithms, this undertaking aims to find optimization strategy/policy for a prosumer Agents.

Data Analysis/ Nature of Dataset:

	A	B	C	D	E	F	G	H	I
1	Timestamp UTC	Customer ID	Power GCP	Power PV	Power EVSE	Power Household	Connection	SoC	Target SoC
2	2021-08-15 00:00:00+00:00	6	347.391643333334	-1.28729298888889	0.0104082751151111	348.668528047108	1		0.3
3	2021-08-15 00:15:00+00:00	6	264.52113	-1.28849173333334	0.0129828152444444	265.796638918089	1		0.3
4	2021-08-15 00:30:00+00:00	6	295.363675555556	-1.32867718888889	-0.0036588120318889	296.696011556477	1		0.3
5	2021-08-15 00:45:00+00:00	6	236.787104444444	-1.31396344444445	-0.0155068148066667	238.116574703696	1		0.3
6	2021-08-15 01:00:00+00:00	6	298.731595555556	-1.29144188888889	-0.00441889842222222	300.027456342867	1		0.3
7	2021-08-15 01:15:00+00:00	6	244.660405555556	-1.32286342222222	-0.00885397795666666	245.992122955735	1		0.3
8	2021-08-15 01:30:00+00:00	6	269.277822222223	-1.33211446666667	-0.0216239776355556	270.631560666525	1		0.3
9	2021-08-15 01:45:00+00:00	6	380.972343333333	-1.36053277777778	0.0321552172222223	382.300720893889	1		0.3
10	2021-08-15 02:00:00+00:00	6	339.108242222223	-1.38396036666667	-0.00192596615222222	340.494128555042	1		0.3
11	2021-08-15 02:15:00+00:00	6	248.668111111111	-1.35191337777778	0.00272179461444444	250.017302694275	1		0.3
12	2021-08-15 02:30:00+00:00	6	162.150124444444	-1.38051144444444	-0.0262805312644445	163.556916420153	1		0.3
13	2021-08-15 02:45:00+00:00	6	159.84276	-1.42080748888889	-0.0351999316566667	161.298767420545	1		0.3
14	2021-08-15 03:00:00+00:00	6	150.79172	-1.41428858888889	-0.0125524829492222	152.218561071838	1		0.3
15	2021-08-15 03:15:00+00:00	6	149.864354444444	-1.43424725555556	-0.0123960167722222	151.310997716772	1		0.3
16	2021-08-15 03:30:00+00:00	6	137.336238888889	-1.49222405555556	-0.0204416709522222	138.848904615397	1		0.3
17	2021-08-15 03:45:00+00:00	6	192.855935555555	0.273577550111112	-0.0198822954322223	192.602240300876	1		0.3
18	2021-08-15 04:00:00+00:00	6	222.357502222222	3.92666090666667	0.0119303367711111	218.418910978784	1		0.3
19	2021-08-15 04:15:00+00:00	6	191.735165555555	-21.578631979	0.0464366378011111	213.267360896754	1		0.3
20	2021-08-15 04:30:00+00:00	6	136.827231213667	-101.796114777778	0.0778663001915556	238.545479691253	1		0.3

The dataset contains samples every 15 minutes of Power Consumed from grid, Power produced by photo voltaic, Current and Target State of Charge and Electric Vehicle Supply Equipment information.

Methodology :

This research will attempt to develop and test an RL-based control system for a household connected to the grid.

Steps :

- Define the system state including solar generation, battery SOC, grid price, EV charging needs, and historical data of household demand.
- Design an action space comprising charging/discharging rates for the battery and grid power purchase/sell amounts.
- Implement a state-of-the-art RL algorithm suitable for continuous action spaces (e.g., DDPG, PPO).
- Develop a simulated home energy management system (HEMS) using libraries like Gymnasium or custom environments.
- Train the RL agent in the simulated HEMS, interacting with the environment and learning optimal control strategies.
- Evaluate the trained agent's performance in terms of metrics like self-consumption rate, cost reduction.

Research Questions:

- **Question 1**: How can Prosumer Agents be modeld in a Reinforcement Learning environment? Can RL effectively optimize self-consumption of PV utilization or minimize cost of energy under time-variable tarrifs ?

- **Question 2**: How does the choice of RL algorithm impact the performance and efficiency of the control system ?

- **Question 3:** What are the key factors influencing the optimal control strategies learned by the RL agent? Can forecasts for the energy price and PV production benefit the prosumer?

Timeline and Work Plan

TimeFrame	Plan
Month 1-2	Literature review, algorithm selection, environment development.
Month 2-3	RL agent implementation, training, and initial evaluation.
Month 3-4	Advanced evaluation, analysis, and result interpretation.
Month 4-5	Thesis writing, report, refinement, and presentation.

Expected Results and Contributions:

This research aims to achieve the following:

- Develop a RL-based control system for optimizing self-consumption or energy cost reduction.

- The potential benefits of the proposed approach in terms of increased self-reliance, cost reduction, and reduced grid dependence.
- Identify key factors influencing optimal control strategies, providing valuable insights for future HEMS design and policy considerations.

References

Some relevant literatures gathered for the application and domain proposed are :

- **"A Survey on Deep Reinforcement Learning for Power and Energy Systems"** by Bo Liu et al. (2020): Deep reinforcement learning: a survey | Frontiers of Information Technology & Electronic Engineering

- **"Reinforcement Learning for Smart Grid Energy Management and Control: Recent Advances and Future Directions"** by Yiwei Song et al. (2021): (PDF) Deep Reinforcement Learning for Smart Building Energy Management: A Survey

- **"Deep Reinforcement Learning for Building Energy Management: A Review"** by Yang Shi et al. (2020): Energies | Free Full-Text | Systematic Review on Deep Reinforcement Learning-Based Energy Management for Different Building Types

- **"Reinforcement Learning for Home Energy Management with a Battery and an Electric Vehicle"** by Y. Zhang et al. (2019): Applied Sciences | Free Full-Text | A Reinforcement Learning Approach for Integrating an Intelligent Home Energy Management System with a Vehicle-to-Home Unit

- **"Deep Reinforcement Learning for Optimal Charging of Electric Vehicles in Smart Grids"** by Z. Li et al. (2020): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9920735/

- **"Optimal Charging of Electric Vehicles Using Deep Reinforcement Learning"** by M. Alam et al. (2020): https://arxiv.org/pdf/2108.07772

- **"Optimal Charging of Bi-Directional Electric Vehicles Using Deep Reinforcement Learning"** by S. Hu et al. (2021): https://www.sciencedirect.com/science/article/abs/pii/S2352467722000716

- **"A Model-Free Reinforcement Learning Approach for Optimal Residential Energy Management Considering Demand Response and Price Prediction"** by Y. Sun et al. (2020): https://www.sciencedirect.com/science/article/abs/pii/S0038092X23002967

Additional Consideration

- University's and organization specific guidelines and requirements for thesis reporting.
- Based on feedbacks, other improvements and consideration.

Regarding Supervision and Collaboration

I hereby request for registration and supervision of my Master thesiswork as per the information above, i plan to start and complete this academic undertaking in collaboration with The Forschungsstelle für Energiewirtschaft e.V. ***(FfE** e.V.)* and submit as a partial fulfillment of my Masters degree of Information engineering at Fachhochschule Kiel (**FH Kiel**) under the supervision of:

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