Machine Learning for Power Systems

Background

Electricity is the foundation of modern society. To deliver electrical power reliably is therefore one of the most central technical challenges of our time. However, traditional methods of power system control are being brought to their limits recently.
Firstly, the traditional top-down topology of power grids is increasingly transforming into more distributed systems. Electric cars can be seen as both high power consumers and flexible energy storage. At the same time, the supply responsibility of large scale power plants is increasingly shared by small scale power generation.
Secondly, the adoption of large scale renewable energy sources means a substantial increase in generation volatility.
Overall, the new generation of power system controllers must be able to deal with a high degree of topological complexity and considerable uncertainty. [1]

Data-driven reinforcement learning controllers are promising candidates because of their ability to learn without precise model knowledge, their on-line efficiency, and their resilience against unknown situations. Quite some research has been done in this area, yet the field is still rapidly growing. [2] [3]

Description

Existing approaches only work on a single reference system and can not be generalized to different size systems. Furthermore, the learned control strategy often only minimizes set point deviation without accounting for more sophisticated elements, e.g. transmission losses, generator efficiency, or fault resilience. Most existing approaches assume full state observability which is not the case in reality. Advances have been made to develop decentralized control strategies, however, these scenarios assume collaboration. Adversarial behaviour is not considered.

The target of the thesis will be to explore the advanced use of machine learning for the control of power systems.

Possible directions of research could be:

- Generate fixed feature space representations of different power grids (possibly utilizing graph neural networks).
- Develop a scenario designer that can automatically generate power grids and fault scenarios based on specific metrics (in the spirit of [4]).
- Investigate the impact of a noisy state observer on the performance of reinforcement learning algorithms.
- Assess the performance and robustness of adversarial multi-agent control.
- Use hierarchical reinforcement learning for multi-objective or multi-level control.
- Explore the options and advantages of combining model predictive control with reinforcement learning.

Tasks

- Review literature of exiting work.
- Build up an understanding of power systems and associated control problems.
- Develop theoretical foundation of the chosen approach.
- Implement the developed approach in Python and test on an existing power system simulation.
- Possibly benchmark the developed approach against traditional controllers.

Technische Universität München

Fakultät für Informatik

Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

Supervisor:
Prof. Dr.-Ing. Matthias Althoff

Advisor:
Michael Eichelbeck, M.Sc.

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For more information please contact us:

E-Mail:
michael.eichelbeck@tum.de

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