Karlsruhe Institute of Technology

Institute for Automation and Applied Informatics (IAI)

Master Thesis

Grid Stability through Flexibility

Scientific Title: How Decentralized Battery Storage Can Mitigate Stress Scenarios in Distribution Networks

As part of the energy transition, distribution networks—especially in the low-voltage (400 V) and medium-voltage (20 kV) ranges—are facing growing challenges. The increasing integration of renewable energy sources and the rising use of new consumers such as heat pumps and charging infrastructure are leading to altered load flows and potential bottlenecks in grid operation.
The goal of this master's thesis is to investigate the extent to which battery storage systems can help relieve existing grid infrastructure—both by reducing the need for grid expansion and by increasing supply security. To this end, stress scenarios will be simulated and evaluated in which targeted deployment of storage systems can mitigate congestion, smooth peak loads, and absorb potential disruptions. The analysis will initially be conducted using a representative low-voltage (400 V) network, but the concept can also be transferred to medium- (20 kV) or high-voltage (110 kV) levels.
In addition to an economic assessment, particular focus will be placed on operational security:

How does the grid behave during unexpected events, such as the failure of battery storage systems under load?
What additional requirements arise in terms of communication, control, and measurement technology to ensure secure grid operation?

The thesis can draw on existing network models and simulation environments (e.g., PowerFactory, Matpower) as well as on the expertise available at the Institute for Automation and Applied Informatics (IAI) at KIT in the areas of modeling, simulation, and visualization.

Tasks:

- Literature review on:
  - Battery storage for grid support.
  - Flexibility modeling in distribution networks.
  - Grid security aspects (e.g., N-1 criterion).
- Use and adaptation of an existing low-voltage (e.g., 400 V) grid model.
- Implementation of battery control models in Python or MATLAB.
- Simulation of stress and fault scenarios (e.g., storage failure under load).
- Analysis of battery storage impact compared to grid expansion.
- Cost comparison of communication and measurement requirements.

What we offer:

- Cutting-edge research on energy transition, grids, and renewables.
- Participation in impactful, real-world research projects.
- Open, flat-hierarchy team culture.
- Work with purpose toward a sustainable energy future.
- Flexible working hours and remote options.
- Mentoring by experienced scientists.
- Friendly, motivated, and interdisciplinary team.

We are happy to answer any questions you might have. Feel free to ask for an appointment or just give us a call!

Die Arbeit darf natürlich auch in deutscher Sprache geschrieben werden.

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Programming language:
PowerFactory, Matpower

Specialization:
Electrical Engineering,
Mechanical Engineering,
Computer Science
or comparable.

Required skills (Wish list):

- Interest in energy supply, grid topologies, and system stability.
- Experience with simulation software (e.g., PowerFactory, Matpower) or willingness to learn
- Programming skills in Python or MATLAB are an advantage.

Language(s):
German, English

Starting date:
As soon as possible or other

Homepage:
https://www.iai.kit.edu/RPE.php

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