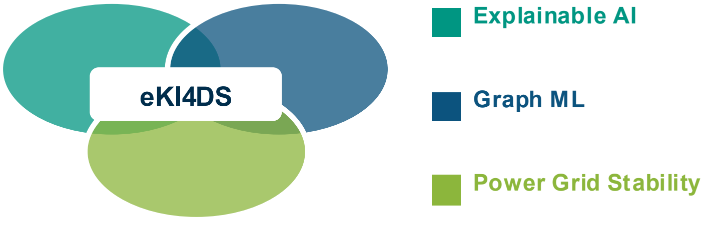
Karlsruhe Institute of Technology

HELMHOLTZ AI

Institute for Automation and Applied Informatics (IAI)

Master's Thesis

Graph ML and Explainability for Power Grid Stability



In April 2025, a minor fault in southern Spain cascaded into a blackout across most of the Iberian Peninsula within seconds, showing how quickly local disturbances can destabilize modern power grids. Power systems demand scalable computational methods for critical tasks such as cascading failure prediction, dynamic stability assessment, AC power flow calculation, and wind power forecasting. Modern power systems face growing complexity as renewable integration, decentralization, and real-time decision-making push traditional model-based methods to their limits. As grid topology fundamentally shapes power system behavior, Graph Neural Networks (GNNs) are particularly well suited to this domain, leveraging network structure as an inductive bias [1].

As GNNs advance toward real-world deployment in applications such as power grid stability assessment, a critical question remains unresolved: whether these models' learned representations are consistent with the underlying system behavior. Explanation methods aim to make GNN predictions more interpretable by highlighting the factors that most influence them, an essential step before such models can be trusted in a safety-critical setting [2]. Still, explainable AI for GNNs in real-world applications remains rather underexplored, leaving many directions open: intrinsic interpretability, post-hoc methods (input/output-based or mechanistic), and counterfactual reasoning.

The eKI4DS project *(Erklärbare KI für dynamische Stabilität)* develops explainable AI methods to assess power grid stability and give network operators clear, trustworthy reasons behind stability predictions. It provides the framework for this thesis, which, depending on the project's current progress and your interests, can take several directions; see the Venn diagram. Possible aspects include:

- Datasets & benchmarks: building Graph ML and explainability datasets via simulation (more engineering-focused)
- Methods: extending state-of-the-art GML or explainability methods for real-world grid applications (more CS-focused)
- Application & validation: applying and comparing existing methods on new datasets, including simulation-based validation (a mix of both)

This topic can also be pursued as part of Praxis der Forschung, the one-year research project practice offered by the Faculty of Computer Science: https://formal.kastel.kit.edu/teaching/projektgruppe/

Study program: Computer Science, Informatics, or a related field (e.g., physics, mathematics, engineering)

Programming language: Python or Julia

Systems and frameworks: PyTorch Geometric, PyTorch, NetworkX/DGL, SHAP, Captum, PowerDynamics.jl, HPC: bwUniCluster 3.0

Skills

Mandatory

- Introduction to Artificial Intelligence course or similar
- Responsible and transparent use of AI

Helpful and recommended

- Data Science and AI for Energy course (lecture or seminar by TT—Prof. Dr. Benjamin Schäfer) or similar

Languages: German or English

Starting date: As soon as possible

Application should include

Mandatory

- Your motivation: which aspect of this topic interests you most, and why?
- Relevant background: favorite courses, project experience, bachelor's thesis, etc. (be concise)

Optional

- Transcript of records

For more information, please contact:
Martin Sadric
martin.sadric@kit.edu

References

[1] Sadric, Pütz, Nauck, Hagenmeyer, Hellmann, Witthaut, Schäfer (2026). Graph Machine Learning: An Opportunity for Power Systems. arXiv:2608.16494.
[2] Sadric, Pütz, Nauck, Hagenmeyer, Hellmann, Schäfer (2026). Assessing Explanations of GNNs for Dynamic Stability Assessment of Power Grids. Proc. 2026 ACM Sustainability Week, 183–199
[3] eKI4DS – Erklärbare KI für dynamische Stabilität. iai.kit.edu/IAI-Projekte_5470.php.