Karlsruhe Institute of Technology

ENERGY LAB 2.0

Institute for Automation and Applied Informatics (IAI)

Data-Driven Discovery of Power Grid Frequency Dynamics using Symbolic Regression and Machine Learning

Xinyi Wen, xinyi.wen@kit.edu

Background

Maintaining the stability of power grid frequency is critical for reliable electricity delivery. Traditional modeling of power system dynamics often relies on known physics-based differential equations. However, modern grids are becoming increasingly complex and nonlinear, making it difficult to obtain accurate analytical models.

Recent advances in data-driven techniques—spanning symbolic regression, machine learning, and probabilistic inference—offer powerful alternatives to traditional physics-based modeling. These methods can identify governing equations directly from time-series data without requiring a complete understanding of the underlying physical processes.

Idea

This project aims to explore and compare modern symbolic regression and machine learning-based techniques for identifying and estimating the dynamic behavior of power grid frequency. The focus will be on using real-world or simulated power grid frequency data to uncover interpretable, representations of system dynamics.

Task

- Implementing symbolic regression techniques to extract differential equations from frequency time-series data. [1, 2]
- Applying machine learning models to support modelling of unknow parameters [3]
- Benchmarking performance of different approaches in terms of accuracy, robustness to noise, and generalization to new power grid frequency data.

References

[1] Brunton, S.L., Proctor, J.L. and Kutz, J.N., 2016. Sparse identification of nonlinear dynamics with control (SINDYc). *IFAC-PapersOnLine*, *49*(18), pp.710-715.

[2] Wen, X., Oberhofer, U., Gorjão, L.R., Yalcin, G.C., Hagenmeyer, V. and Schäfer, B., 2024, June. Identifying Complex Dynamics of Power Grid Frequency. In Proceedings of the 15th ACM International Conference on Future and Sustainable Energy Systems (pp. 408-414).

[3] Pillonetto, G., Aravkin, A., Gedon, D., Ljung, L., Ribeiro, A.H. and Schön, T.B., 2025. Deep networks for system identification: a survey. Automatica, 171, p.111907.

Institute for Automation und Applied Informatics (IAI)
Karlsruhe Institute of Technology, Campus North
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen