Bachelor thesis

Simulation models of electric drives focusing fault scenarios

Control-oriented models of electric drives typically consider nominal operation conditions. However, in practice, electric drives are subject to various fault scenarios, such as short circuits, bearing faults, or thermal faults as well as issues associated with the feeding inverter like driver or semiconductor faults [1], [2]. These faults can significantly impair the drive operation and change the drive's behavior which needs to be considered by the control system. To develop and test controllers which are robust against such faults, it is necessary to have accurate models of the electric drive system that can be used to simulate these fault scenarios and predict their behavior in abnormal conditions. However, in contrast to nominal drive models, e.g., the dq-based model of a permanent magnet synchronous machine or of an induction machine, which rely on symmetry assumptions leading to rather straightforward and small models, faults typically break these symmetries and require more complex models (e.g., in abc phase coordinates). The goal of this thesis is to develop such models for electric drives and to implement them in a simulation environment.

(a) Damaged motor bearing
(source: https://renown-electric.com)

(b) Burned motor windings
(source: https://www.simomotor.com)

Key research questions:

- How to modify the dynamic drive models for different fault scenarios?
- How do the drive faults impact the dynamic system behavior?
- How to implement these faults in a simulation environment?

Necessary requirements:

- Finished course work on electrical machines and power electronics
- Interest in modeling and simulation of differential equations
- Interest or experience in scientific programming languages (e.g., Julia, JAX, PyTorch)

WP 1: Literature research **[3 weeks]**
Scanning the scientific literature for relevant publications and patents related to most common faults in electric machines and feeding power electronic converters is the first step. Moreover, relevant (open-source) software work in the field should be considered (e.g., PYLEECAN). This also includes the identification of relevant keywords as part of the search strategy. Relevant work will be stored in a literature review software (e.g., JabRef) and summarized in the thesis.

WP 2: Mathematical models **[4 weeks]**
Based on the identification on the most common electrical and mechanical faults in electric drives, the corresponding mathematical models should be developed, that is, sets of differential equations including descriptions of the electromagnetic machine behavior. The starting point for that should be permanent magnet synchronous machine drives and eventually induction machine drives depending on the overall workload and time budget. For each fault case an appropriate coordinate system should be chosen (abc, $\alpha\beta 0$, dq0).

WP 3: Model implementation **[4 weeks]**
To allow a fast inference of the different fault models, the implementation should be done in just-in-time compilable languages like Julia or JAX. This includes the selection of appropriate numerical solvers for the underlying differential equations and the configuration of the simulation environment. The overall environment should also be equipped with an API (application programming interface) to allow for easy integration into other simulation environments.

WP 4: Empirical comparison **[2 weeks]**
Based on the literature review from WP1 already published test cases should be used to compare the developed models with existing data (at least qualitatively, i.e., plotting the simulation results and compare them with plots from the literature). The comparison should be done for different fault scenarios and different operating points of the electric drive.

WP 5: Documentation **[3 weeks]**
All work packages should be reported in a structured way within the thesis. A LaTeX template should be used for this purpose: `https://github.com/IAS-Uni-Siegen/thesis_latex_template`. Writing instructions can be found within the provided template source files. Based on the previous empirical findings, conclusions should be drawn, and future research directions should be outlined.

Gantt chart

The planned timetable is shown in the Gantt diagram below.

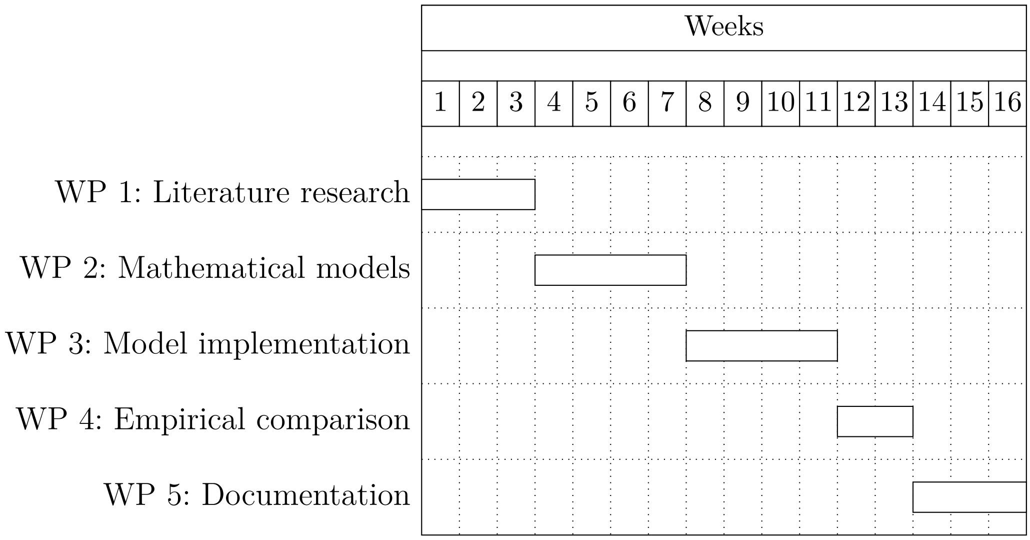

Figure 2: Gantt chart for the thesis.

References

[1] P. D. Strankowski and J. Guziński, "Faults and fault detection methods in electric drives," in *Soft Computing in Condition Monitoring and Diagnostics of Electrical and Mechanical Systems: Novel Methods for Condition Monitoring and Diagnostics*, H. Malik, A. Iqbal, and A. K. Yadav, Eds. Springer Singapore, 2020, pp. 57–69.

[2] A. Singh, B. Grant, R. DeFour, C. Sharma, and S. Bahadoorsingh, "A review of induction motor fault modeling," *Electric Power Systems Research*, vol. 133, pp. 191–197, 2016.