Advanced Hybrid Modeling Techniques for Electrical Propulsion Drive System (EPDS) of Software-Defined Vehicles (SDV)

Summary

This PhD project aims to advance the modeling of Electrical Propulsion Drive System (EPDS) in Software-Defined Vehicles (SDVs) by leveraging hybrid, multi-domain, and multiscale modeling approaches. The project's objective is to develop a unified framework that integrates physics-based and data-driven methodologies to enhance the modeling fidelity of EPDS, bridging the gap between component-level and system-level perspectives. This research addresses the need for more comprehensive and computationally efficient models that account for the interactions between electrical, mechanical, electrochemical, and thermodynamic domains.

Research field:	Electrical power engineering and mechatronics
Supervisors:	Prof. Dr. Anton Rassõlkin Mahmoud Ibrahim Hassanin Mohamed
Availability:	This position is available.
Offered by:	School of Engineering Department of Electrical Power Engineering and Mechatronics
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The PhD candidate will build upon pre-existing models from the prior PRG2532 project and introduce advanced modeling techniques to capture complex phenomena affecting EPDS. Empirical data collected from experimental activities will be utilized to validate these models and improve their predictive accuracy. Additionally, the project will explore the impact of environmental factors, such as temperature, humidity, and terrain, on EPDS performance, integrating these effects into the unified modeling framework. This approach will ensure robust, scalable, and computationally efficient models that support the design and control of SDV EPDS.

The main tasks of the thesis are:

1. Understanding of the main concept of cyber-physical systems, digital twins, and SDV

- Conduct a comprehensive literature review in the field of Cyber-Physical Systems (CPS), Digital Twins (DT) use in SDV to gain a deep understanding of the concepts, applications, and integration.
- Analyze current trends, methodologies, and challenges in the field to identify research gaps and potential areas for innovation.

2. Research into state-of-the-art technologies and methodologies

- Identify and review state-of-the-art technologies and methodologies related to CPSs, DTs, and SDVs.
- Explore recent advancements and emerging trends in these areas, including modeling techniques, simulation tools, scaled demonstrators, and integration strategies.
- Review and analyze existing analytical, numerical, and data-driven models from PSG453 and PRG2532 .
- Identify limitations of the existing models and propose strategies for improvement.
- Develop and enhance the models to support component-level (micro) and system-level (macro) perspectives of EPDS in SDVs.

3. Multi-domain modeling and integration

- Incorporate multi-domain modeling techniques that capture the interactions between electrical, mechanical, electrochemical (batteries), and thermodynamic domains.
- Ensure that the models reflect the holistic behavior of EPDS components and subsystems.
- Address cross-domain interactions and their impact on system performance.

4. Development of hybrid modeling approaches

- Develop hybrid modeling techniques that combine physics-based and data-driven approaches.
- Apply multiscale modeling methods to bridge the gap between component-level (micro) and system-level (macro) analysis.
- Develop computationally efficient reduced-order models that maintain a balance between fidelity and speed.

5. Empirical validation of the proposed models

- Validate the developed models using empirical data collected from experimental tests and prior simulation results.
- Conduct sensitivity analysis to evaluate model robustness under varying operational conditions.
- Compare model outputs with real-world data to ensure high predictive accuracy.

The applicants should fulfill the following requirements:

- Master's degree in electrical engineering or mechatronics
- Familiarity with multi-domain simulation tools and techniques.
- Experience with common scientific software (e.g. Matlab, Simulink, Octave, Pyton, etc.)
- Experience with common research support software (e.g. Office 365, Mendelay, LateX, etc.)
- Practical experience with EPDS
- Practical experience with modeling electrical drives, batteries, or other EPDS components.
- Practical experience with publishing and presenting research works (e.g. conference papers)
- Very good command of English

Fluent Estonian language skills in written and oral communication are desirable but not mandatory

About the department

The Department of Electrical Power Engineering and Mechatronics of Tallinn University of Technology is an interdisciplinary research centre focusing on socially relevant and future-oriented research and teaching issues related to power engineering and mechatronics. The department’s mission is to lead electrical engineering and technical studies and development projects in Estonia, which is known and valued in society and is a respected partner in national and international cooperation networks and organizations. The department has coordinated and partnered with several international projects, including Horizon 2020, INTERREG, 7FP, Nordic Energy Research etc.

The Department of Electrical Power Engineering and Mechatronics conducts research within seven research groups and operates state-of-the-art laboratories with high-end equipment, offering accredited services in lighting and different electrical measurements. The department’s focus areas are domestic and global challenges related to increasing digitalization, decarbonization, and decentralization of electric power systems and the increasing use of renewable energy sources. The department carries out research in the following relevant areas:

- optimization of electric power systems and system analysis to find possibilities for electrification and decarbonization
- diagnostics and monitoring of equipment and systems
- cyber security, 5G data communications and artificial intelligence
- energy networks and research on green technology, including energy storage, renewable energy, hydrogen systems
- supply and demand-side management, IoT applications in energy systems
- implementation of smart industry, including industrial robotics, automation, 3D printing, computer vision, digital twins

To get more information or to apply online, visit https://taltech.glowbase.com/positions/924 or scan the the code on the left with your smartphone.