École Polytechnique Fédérale de Lausanne
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Student project proposal

Project title

Design and Experimental Validation of an Electromagnetic Levitation Controller for a Hyperloop Pod

Project type ☒ MSc thesis ☐ BA semester project ☐ MSc semester project

Project responsible and e-mail
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Project description

The proposed project is part of the epfloop team's research into the electrification of transport, and more specifically into the propulsion and levitation of high-speed vehicles (referred to as pods) [1]. The goal of the project is to design, implement and experimentally validate a control algorithm for the electromagnetic levitation system of a Hyperloop pod. The pod is lifted by four levitation units, each producing an attractive electromagnetic force towards the track. Such an attractive levitation system is highly nonlinear and inherently unstable in open loop: without active control, the pod either falls or snaps onto the track. The controller must therefore continuously adjust the currents in the levitation units, based on air-gap and current measurements, to hold the pod at an air gap of a few millimetres.

Since the four units act on the same rigid body, they are dynamically coupled. The expected outcome of the project is therefore a controller for the full pod, stabilising its heave, pitch and roll motions and tracking a desired air-gap trajectory (e.g. take-off, landing and changes in levitation height). Its performance will be assessed in terms of stability, air-gap tracking accuracy, rejection of disturbances (e.g. load changes) and robustness to variations in the pod mass.

The project consists of two phases. The first phase covers the modelling of the levitation system, the design of the controller in simulation, and its implementation and experimental validation on the pod under static operating conditions (no motion of the pod). The second phase, building on the results of the first, consists in implementing the decoupled propulsion–levitation control proposed in [2] and testing it under dynamic conditions on the epfloop circular infrastructure.

Tasks of the student

- Become familiar with the pod and its four levitation units (electromagnets, power converters, sensors, onboard controller).
- Conduct a literature survey of existing control strategies for attractive electromagnetic levitation systems, from single-magnet set-ups to multi-magnet vehicles.
- Model the levitation system:
  - Derive a nonlinear model of the pod dynamics in heave, pitch and roll.
  - Identify the model parameters from measurements on the levitation units.
- Design and tune a suitable control algorithm for the full pod.
  - Implement and test the controller in Simulink (or an equivalent simulation environment), including realistic effects such as sampling, delays, sensor noise and voltage/current limits.
- Implement the controller on the onboard controller (sbRIO).
  - The control will run on the FPGA of the sbRIO.
- Conduct real-time levitation experiments under static conditions, first with a single levitation unit and then with the full pod.

- Implement the decoupled propulsion–levitation control [2] and test it under dynamic conditions on the epfloop circular infrastructure.

Requirements

- Strong background in control theory (state-space and digital control).
- Basic knowledge of electromagnetics and electromechanical energy conversion.
- Basic knowledge of power electronics, electronics and embedded systems.
- Proficiency in MATLAB/Simulink; experience with LabVIEW (ideally LabVIEW FPGA), or strong willingness to learn it.
- Interest in hands-on laboratory work and experimental testing.

This project offers the opportunity to combine theoretical control design with hands-on experimentation on a real prototype.

Literature

[1] www.epfloop.ch

[2] S. Rametti, L. Pierrejean, A. Hodder, and M. Paolone, 'Decoupled Levitation and Propulsion Control of Single-Sided Linear Induction Motors', in 2024 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC), Naples, Italy: IEEE, Nov. 2024, pp. 1–6. doi: 10.1109/ESARS-ITEC60450.2024.10819927.