A performance-based standard for electrified converter dolly combination

Background

The performance-based standard (PBS) framework is a framework to introduce functional requirements of high capacity (HCT) vehicles, [1]. The main idea behind this framework is to express a performance that a vehicle should meet in order to be legal on the public road network. This contrasts with the more conventional way of describing legal requirements in a prescriptive manner, e.g., the maximum legal length of a vehicle combination must not be longer than 25.25 meters. Instead, the vehicle length may be bounded by the rearward amplification, its ability to negotiate roundabouts etc.

For each PBS there is an associated test and a metric that measure the performance in this test. The tests are often grounded in traffic safety or the ability to respect the geometry of the road and not cause traffic congestion or damage the infrastructure. One example is the so-called off-tracking that a long HCT vehicle will experience. The test, in this case, is a simple steering maneuver and the metric is how wide a lane the vehicle combination needs to complete the maneuver. The requirement is then expressed in a maximum lane width that the vehicle combination may use. Another example is startability, where the test is starting on a slope and the metric is defined by the slope grade. The PBS framework is designed for test track assessment, but for convenience often assessed in simulations.

The HELPED project is a research project within the vehicle dynamics group at Chalmers. The aim of this project is to evaluate aspects of introducing an electrified converter dolly (edolly) with propulsion. A converter dolly is a small vehicle intended to convert the connection of a trailer from a drawbar to a fifth wheel, see figure below.

![Figure 1 An example of a dolly converter vehicle. From Wikipedia. By Teppo Lainio - Own work, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=456523](https://commons.wikimedia.org/w/index.php?curid=456523)

Introducing an (electrically) propelled axle on a dolly converter vehicle is motivated by a flexibility argument, where existing vehicles in a vehicle combination can be used without modification, and the fact that an electrified axle can increase the fuel efficiency of the internal combustion engine of the primary mover.
With predictive control, there is a potential to save fuel using the extra energy buffer that the electrified axle and its battery provide and allowing some deviation of the longitudinal speed. However, with actuation on more axles in the vehicle combination comes the risk of creating dangerous situations. Energy efficiency and traffic safety can be dealt with simultaneously using optimal control strategies, see [2].

**Problem description**

With the possibility to improve the energy efficiency of the vehicle combination by introducing an edolly comes the risk of controlling the electrified axle in a way that can produce dangerous situations, e.g. so-called jack-knifing, etc. From a legal perspective, and in particular, in the PBS spirit it is not desirable to be prescriptive, e.g. prohibit energy recuperation in curves. Hence, introducing edollies on the road network in a safe manner represents a challenge by describing how performance should be respected by the new vehicle combinations containing the edolly.

**Research question**

The core of the project is to investigate the PBS framework with respect to safety for vehicle combinations containing an edolly. Concrete questions that should be considered in the project are.

- Is the existing PBS framework enough w.r.t safety for vehicle combinations with edollies?
- Is it possible to derive new conditions and tests that can rule out bad and dangerous control of the edolly?

**Deliverables**

- Models and tests of vehicle combinations containing edollies
- A study of safety for these combinations with respect to existing PBS framework and possible control strategies
- Potential proposals for new PBS tests and metrics for edolly control

**Tentative plan**

- A literature study and read up on the PBS framework
- Deriving simple enough models, in alignment with existing models in the PBS framework
- Simulation studies

**Administrative**

- Number of credits: 30 points per student (nominally 20 weeks).
- **Starting date:** any time
- **Requirements:**
  - Good understanding of system dynamics
  - Good understanding of modeling (vehicle dynamics preferable)
  - Knowledge and skill in a modeling and simulation tool (e.g. Modelica, Simulink/Matlab etc)
  - Good understanding in control systems (preferably MPC and optimal control)
- **Resources/Stakeholder:** Chalmers and Volvo (the thesis will be strongly connected to the HELPED project and the partners within this consortium).
- **Responsible subject/research group at Chalmers:** Vehicle dynamics
  - Examiner: Fredrik Bruzelius
  - Supervisor
    - Fredrik Bruzelius
    - Toheed Ghandriz
- Application to Fredrik Bruzelius, fredrik.bruzelius@chalmers.se, with CV and transcripts.
- **Physical location:** Chalmers and possibly also at Volvo GTT

**References**
