Assignment 2 in the course “Hybrid Vehicle Drives” 2020

Electric Roads vs Hydrogen

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Background

Even if it is proven that full electric road vehicles can “do the job” of a corresponding combustion driven vehicle, it is still just barely when it comes to range and it is at the cost of large, heavy, expensive and environmentally questionable batteries. To reduce the amount of batteries in these vehicles there are two alternative engineering solutions that are currently discussed and evaluated.

1 Electric road systems (ERS). By providing energy transfer along the road the need for batteries can be significantly reduced, at the cost of a new charging infrastructure. However, the ERS is not present everywhere, but typically comes in section of e.g. 1 km of every 2 km, and the battery is correspondingly cycled every such section, which of course ages the battery. The reduced size of the battery and the cycling due to ERS sectioning affect battery cost in opposite directions. It is thus interesting to investigate how this adds up to the operational cost.

2 Hydrogen fuel cells (FC). By carrying a tank of hydrogen and a fuel cell on board, the need for batteries can be significantly reduced at the cost of substantial additional equipment on board, the addition of an almost non-existent hydrogen infrastructure and questionable efficiency. The higher the fuel cell system power, the less battery can be used, but on the other hand the more expensive the fuel cell system is and the more cycled the battery becomes. It is thus interesting to investigate how a balance between fuel cells and batteries adds up to the operational cost.

The assignment is to compare these two alternative methods to reduce the amount of batteries in an electric vehicle in terms of cost, energy efficiency and transport capability.

You are given a simulation model that can act as either I) a battery electric for fast charging only, II) a fuel cell & battery or III) a battery and ERS vehicle. The simulation model also contains a cycle life counter that can calculate the fraction of battery lifetime consumed in a specific use, like in one drive cycle simulation. You need to install the Signal Processing toolbox in Matlab to use it.

We know the following about the ingoing technologies:

1 EV batteries cost 100 Euro/kWh and have a lifetime that depends upon the DoD of each cycle (every drive cycle contains many DoD cycles of different depths).

2 The ERS “pick up” on the vehicle cost 1000 Euro for a car and 3000 Euro for a truck, and weights 70 kg + 1 kg/kW for a car and 120 kg + 1 kg/kW for a truck. The ERS pickup and related equipment on board is expected to have a lifetime of 130 000 km for a both a car and a truck.

3 An average car drives 13 000 km/year and a truck drives 100 000 km/year.

4 The FC efficiency properties are given in the simulation model.

5 The different charging efficiencies are given in the model. (Static slow charging, ERS charging). This is important since it is the amount of primary electric energy used that is important. That is affected by the charging efficiencies with night-time charging and not least in the making of hydrogen from electricity by electrolysis.

6 In the cases where a drive cycle ends with a much lower SOC than it started with, we assume that the battery is recharged to the starting SOC by night time charging.

The assignment

1 Find and select a cost and weight model for the Fuel Cell related equipment on board the vehicle, including hydrogen tank and the FC system itself. The figures you want to get are [Euro/kWh & kg/kWh] for the tank and [Euro/kW & kg/kW] for the FC. It is easier to find volume density [liter/kW] than weight density [kg/kW] for batteries. If you need, make assumptions that you motivate.

2 Find and select an efficiency model for Hydrogen production from electrolysis, distribution, and filling (the tank).

3 Optimize a car and a long-haul truck, with weight and size specifications as given in the model, to a combination of battery and FC that you think is best and motivate your choice. Let the Car run the WLTP3 cycle 5 times in a sequence and the Long-Haul Truck run the "Long Haul 3" cycle.

4 Optimize the battery on board the vehicle in the ERS case by varying the "d_ers"-distance, which is the distance between every new start of an ERS track (typically 1…30 km).

5 To your help you have a simulation model prepared with FC efficiency and an ERS supply which can be used either one or the other but not both in the same vehicle.

6 Make a comparison of the three vehicle versions: I) The full electric battery only vehicle, II) The full electric battery and FC vehicle and III) The full electric battery and ERS vehicle, in terms of:

   a. Primary electric energy consumption.

   b. Cost for ageing of the battery, hydrogen tank, fuel cell and pick up (content depending on vehicle).

   c. Load carrying capacity difference depending on the weight of batteries, hydrogen tank, fuel cell and pick up (content depending on vehicle).

7 Discuss the conclusions you draw from the optimisation and comparison that you have made. How do you think the supply infrastructure (ERS road network vs Hydrogen filling stations network) will affect the cost comparison? What does the availability of excess amounts of renewable electricity mean for the operational cost?

8 Write a report presenting the thoughts behind your solution and the results, supported with a presentation of your simulation model, your control strategy and simulation results. Submit the report by e-mail to Meng no later than **Oktober 18th**. Use the filename student1_student2_assigment2…". The report must be complete including front page and table of contents, all in one file. The report must be in "pdf" or Microsoft Word format.