

HYBRIDIZATION OF LIGHT RAIL SYSTEMS

We consider the displacement of a light rail system (Alstom – CITADIS) along a test line 1.5 km long. The electric vehicle power (P_{elec}) at the overhead contact line is simulated thanks to a global simulator of mechanical and electrical parts.

The data profile at a sampling period equal to 1s is described in `donnees.mat` file. Calculations can be performed in the Matlab © environment.

You will take the following convention on signs:

- P_{elec} is positive for traction mode (corresponding to a phase of discharge of storage);
- P_{elec} is negative for braking mode (corresponding to a phase of charging storage);

Use the following script in order to define a P_{elec} variable from the Matlab structure :

```
Pelec = [T.pelec];
```

1) Characterization of the load profile

Plot the load profile and analyze the different durations of braking or accelerating modes of the vehicle. Without any On-Board Energy Storage System (ONESS), plot the cumulated energy supplied by the grid and calculate the global energy supplied by the grid for one way.

From the power supply profile, you have to determine the Potential of Hybridization in Power (PHP) and the Potential of Hybridization in Energy (PHE). Conclude about the interest of hybridizing the engine with an auxiliary source (for instance, an ONESS). From the PHE, deduce the main constraint for the sizing of the ONESS.

2) Energy Management System

Propose a **first** and adapted EMS for a frequency power sharing between the grid and the ONESS. Justify your choices considering :

- The characteristics of the electrical grid,
- The characteristics of the vehicle pathway,
- The characteristics of a light rail vehicle.

3) Choosing Storage Technology

Assuming this last EMS, and using `spectre.m` function, determine the frequency spectrum of the load profile. Conclude about the choice of technology(s) for the ONESS.

4) Sizing of the ONESS

a) From the power profile of the ONESS proposed at Q.2, calculate:

- The **actual** power provided by the storage device, taking overall conversion efficiency (converters and losses of the storage facility);
- The energy actually stored in the device (=cumulated energy at any time).

b) Do you need to adapt the EMS at this step ? Explain and propose some adaptations if any.

c) With these power and energy profiles, calculate:

- the useful energy for the ONESS for one-way only;
- the total capacity of the ONESS, taking into account of the Depth of Discharge for the chosen technology.

From the choice of your technology, and only for one technology, propose a complete sizing of the ONESS.

For storage systems as batteries or supercapacitors, you will have to have to propose the architecture of cells and some sizing elements for the DC/DC converter.

For storage system as flywheels, you will have to size the wheel and the associated motor.

5) Analysis and optimization

From the parameters of the EMS, propose an optimization of the ONESS design in order to reduce the cost of the solution while respecting the preceding constraints.

Conclude about the interest of hybridization for this application.

Characteristics and data sheets of supecap, flywheel and Li-ion batteries are given in the Annex file.

