IEE/SEM/Master SGB
Duration : 6h

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:
- Pelec is positive for traction mode (corresponding to a phase of discharge of storage);
- Pelec is negative for braking mode (corresponding to a phase of charging storage);

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) Choosing Storage Technology

Assuming that the ONESS is used when the grid only supplies the mean power of the load profile, and using spectre.m function, determine the frequency spectrum of the load profile. Conclude about the choice of technology(s) for the ONESS.

Propose a **first** and more adapted EMS for a frequency power sharing between the grid and the ONESS.

3) Sizing of the ONESS

<u>We assume that supercapacitors, or Li-ion batteries, or flywheel systems are consistent with the preceding analysis.</u>

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

- 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.

4) 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.

ANNEX

Data sheet for supercaps (example)

series resistance element (ESR)	350 µΩ
Capacitor	5000 F
Voltage	2.5 V

Table 1 Characteristics of EPCOS (B49410B2506Q000) data element

Data sheet for batteries (example)

Rated capacity	135 A.h (C5)	Rated discharging current (I5)	27 A
Rated voltage	1,2 V	Rated charging current (I1)	40,5 A
Maximal discharging current	2,5 * C5	Maximal charging current	1*C5