Final Event
24-25th of May 2022

Powerful Advanced N-Level Digital Architecture
for models of electrified vehicles and their components

SNCF's use case – EMR and control of a fuel cell locomotive for consumption assessment

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Collaboration with

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CO2 emissions from traction and particularly diesel traction

86%

of SNCF Voyageurs CO_2 emissions come from traction…

… and more particularly diesel traction, which nevertheless represents a moderate share of traffic

CO2eq repartition — 678 ktCO2eq

Electric traction
50% des tCO2eq

Diesel traction
50% des tCO2eq

trains.km repartition — 355 M trains.km

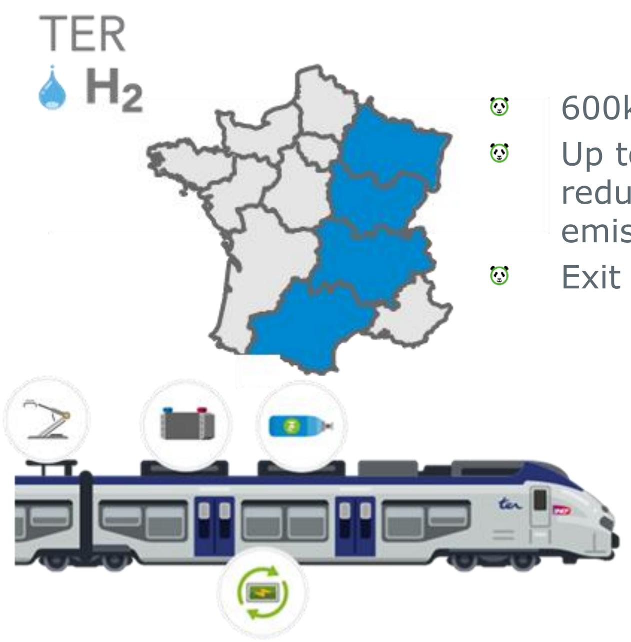
Electric traction
87% des km

Diesel traction
13% des km

SNCF Voyageurs Data, 2021

The hydrogen train challenges

- First order for 12 trains for circulation from 2025



- 600km range
- Up to 70% CO_2 reduction and no local emissions
- Exit from fossil fuels

ECOLOGICAL

"Zero emission" solution to non-electrified regional traffic

TERRITORIAL DEVELOPMENT

Mutualizaion of local ecosystems

ECONOMIC

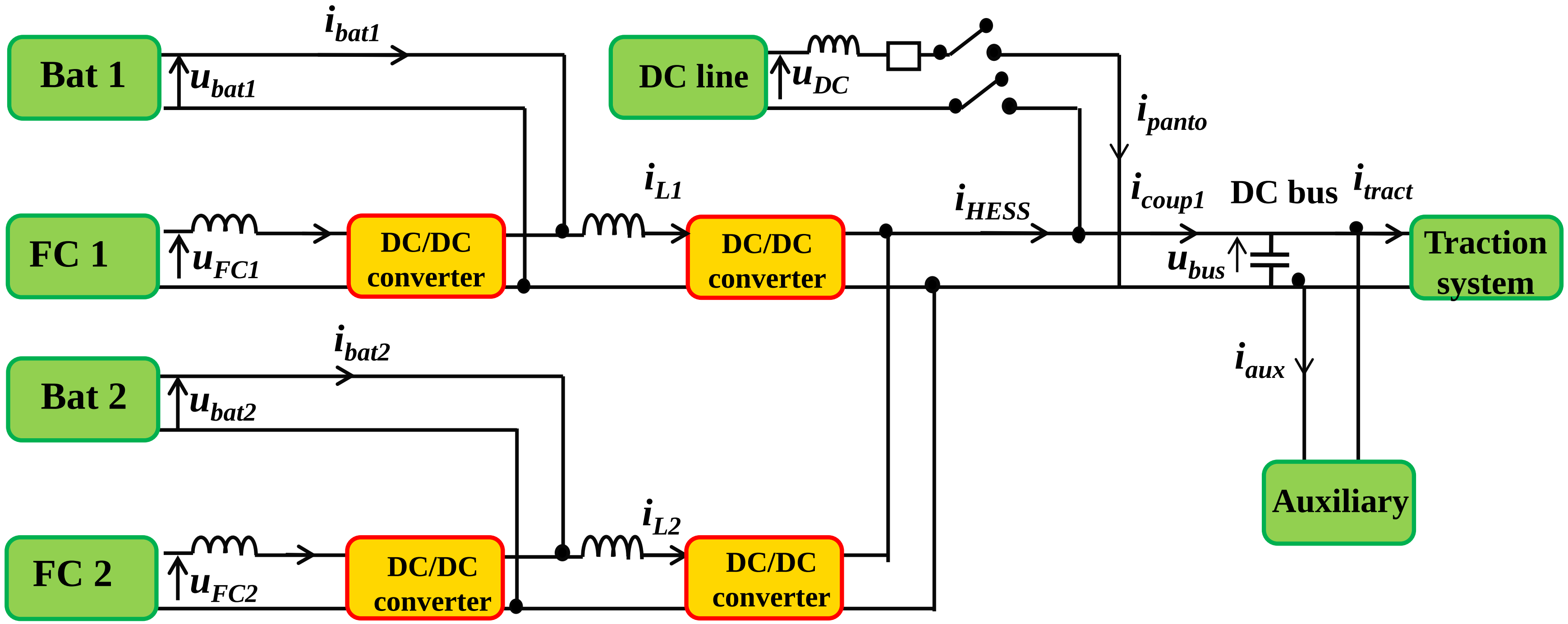
Alternative to electrification or regeneration

INNOVATIVE MOBILITY

A clean source of energy and innovative traction

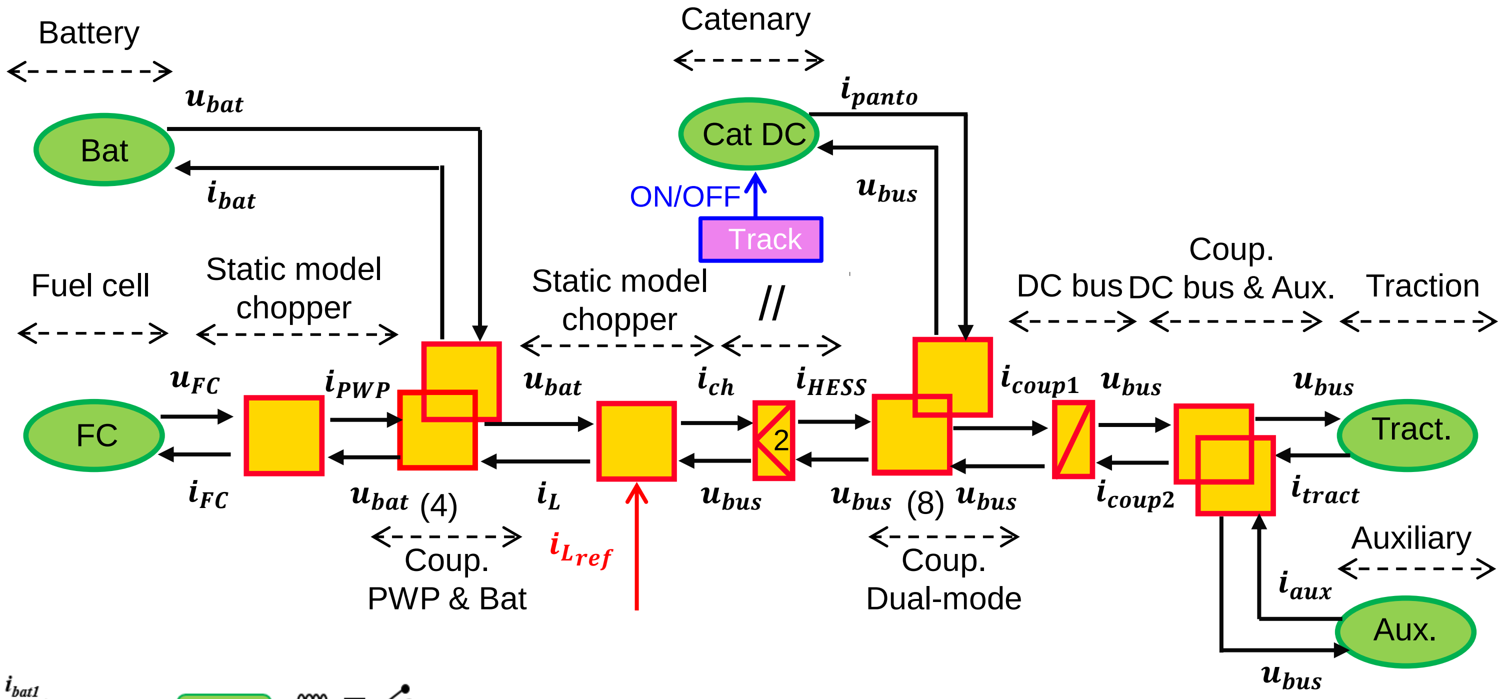
To reduce the operating costs of H2 trains, it is necessary both to have a cheaper H2 and to improve the performance of the trains.

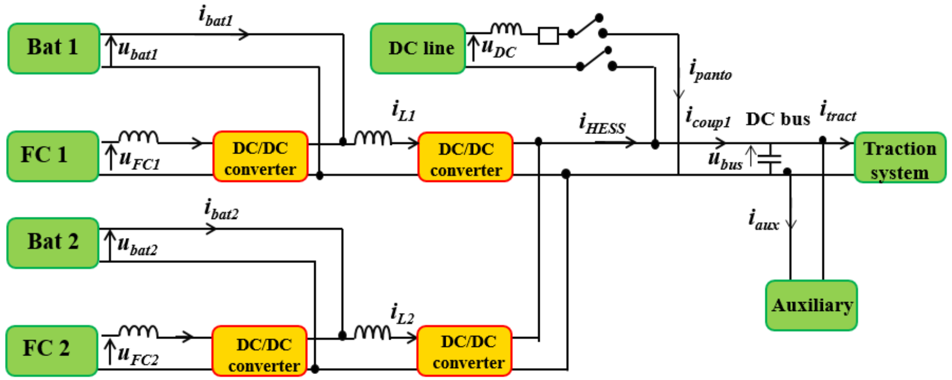
The studied fuel cell hybrid dual-mode train is a complex multi-source system



The identification of local control constraints and management objectives represents a challenge: the Panda method is used

EMR of the energy storage and generation system

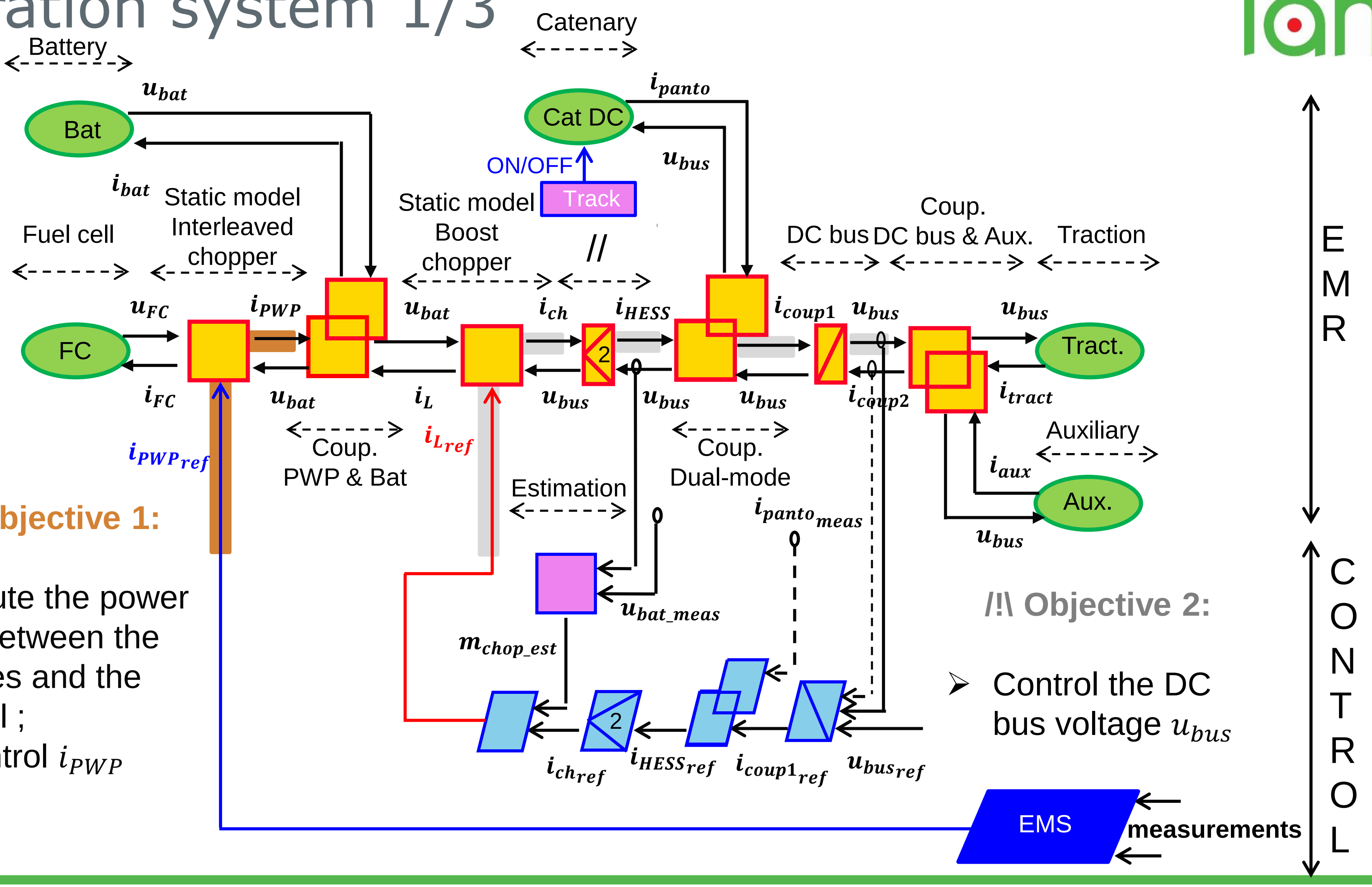




- Assumption: same operations points for both Bat/FC subsystems

EMR and control of the energy storage and generation system 1/3

- Control in non-electrified track



/!\ Objective 1:

Distribute the power flows between the batteries and the fuel cell ;

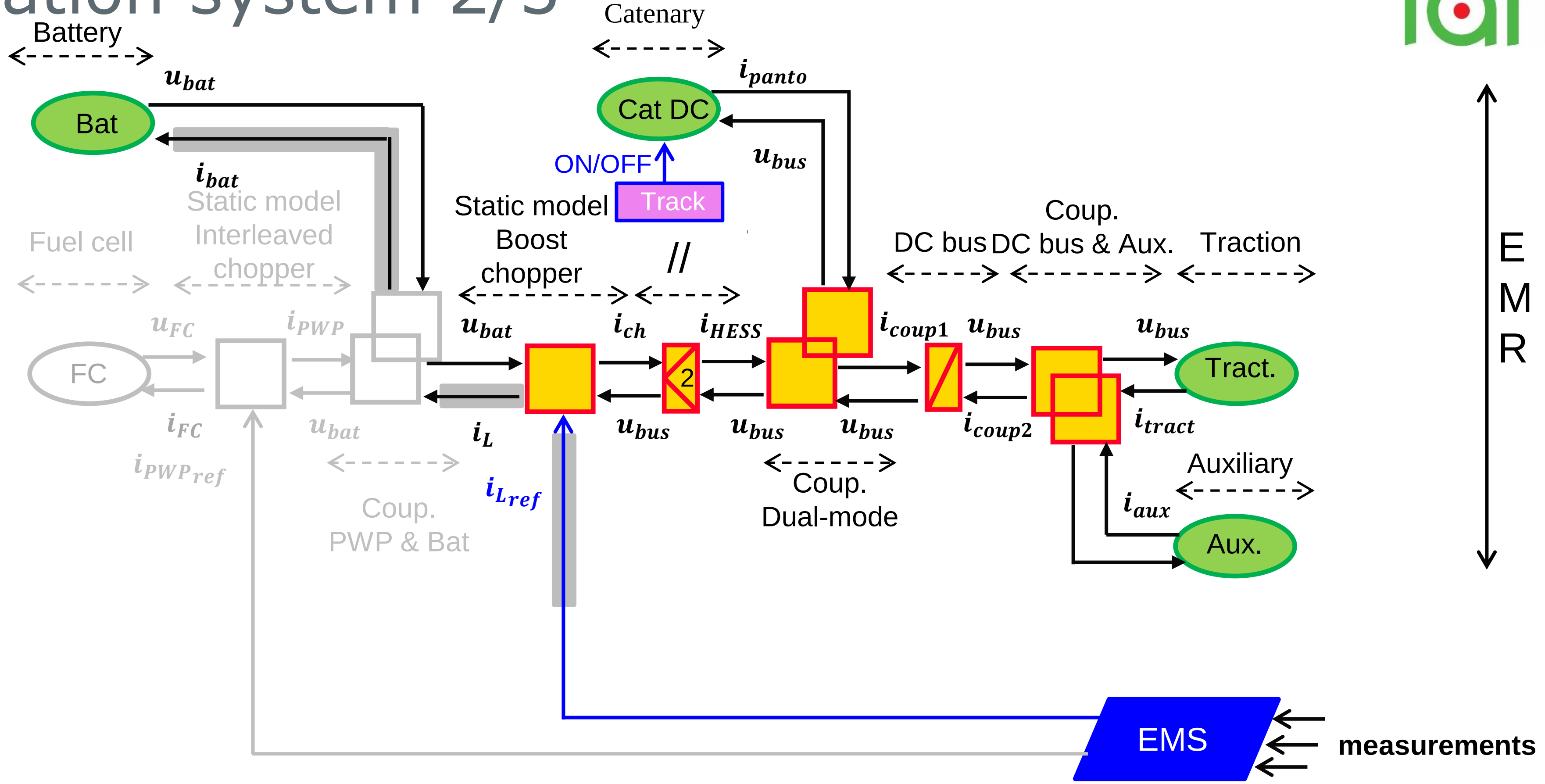
- Control i_{PWP}

/!\ Objective 2:

- Control the DC bus voltage u_{bus}

EMR and control of the energy storage and generation system 2/3

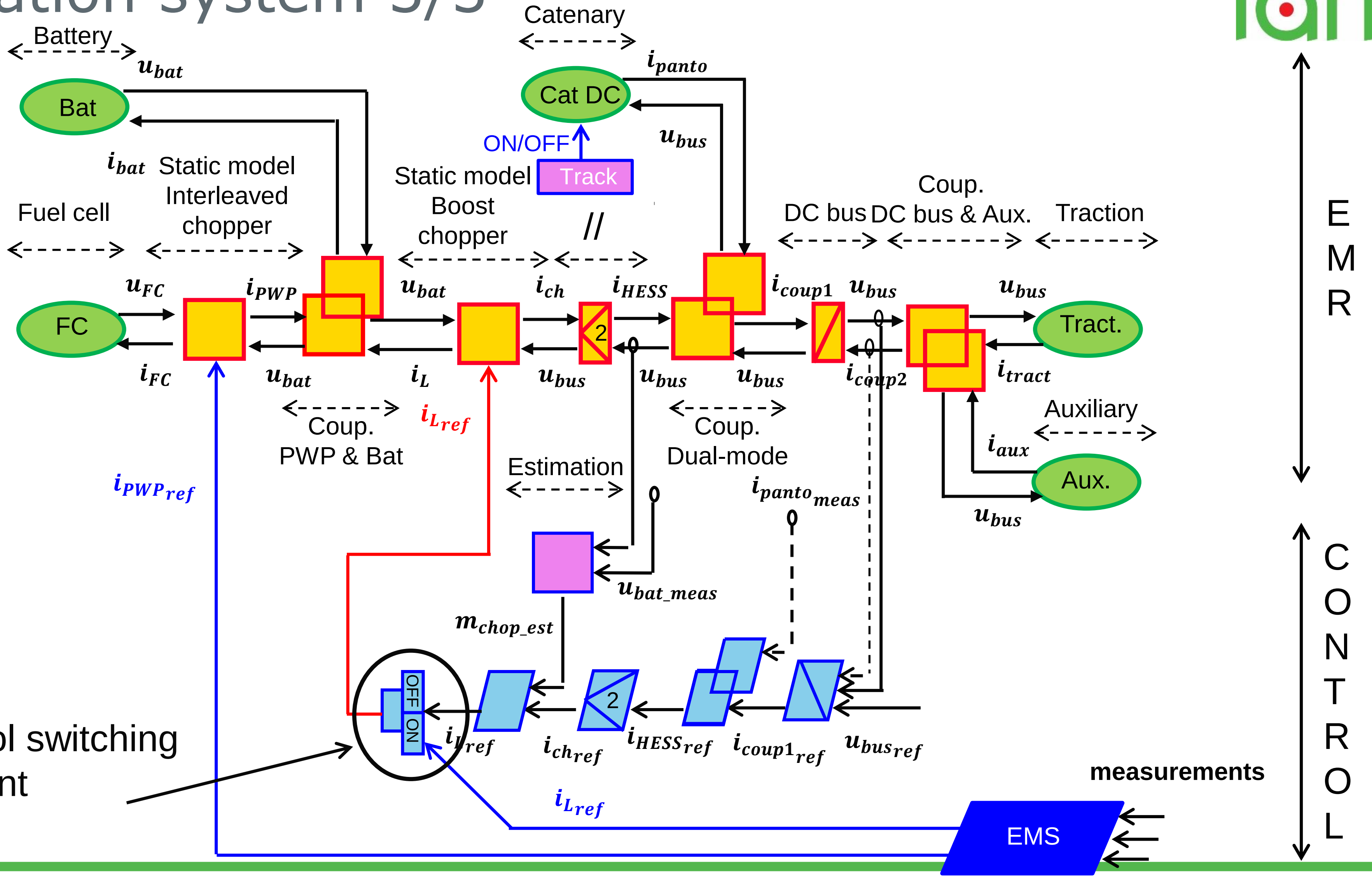
- Control in electrified track



- The DC bus voltage is not controlled by the fuel cell PWP/battery system.
- The Fuel cells are disconnected

EMR and control of the energy storage and generation system 3/3

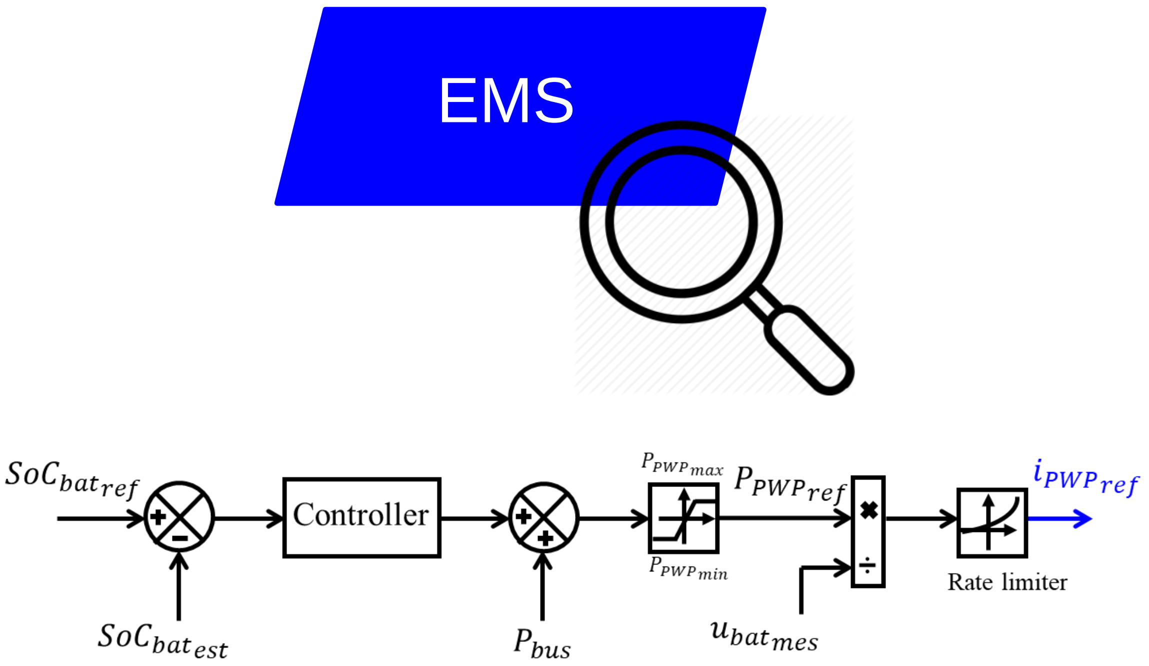
- Unified control scheme



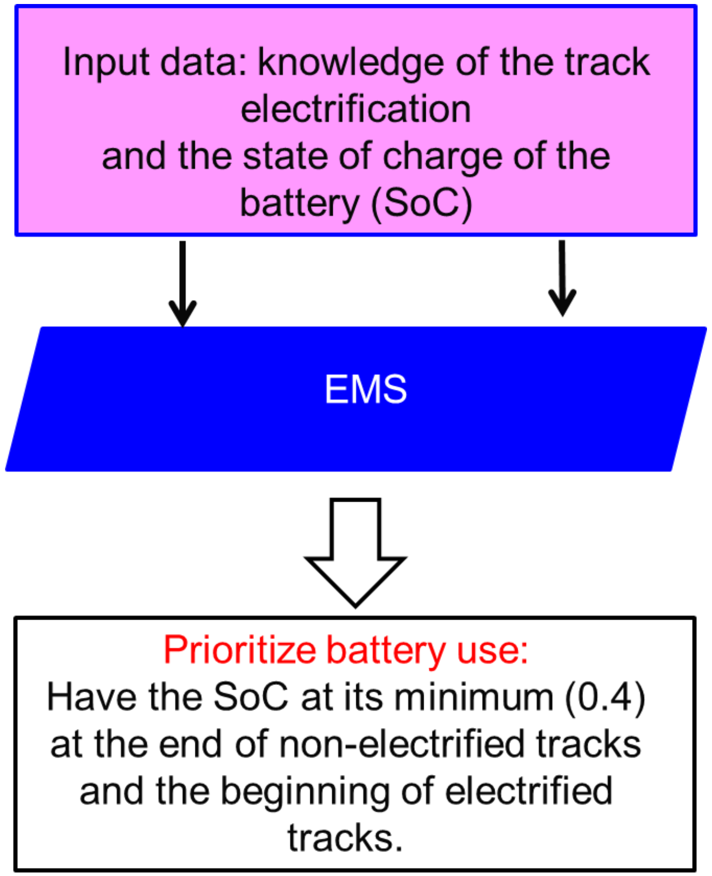
Control switching element

How to consume less H2? Two management strategies applied

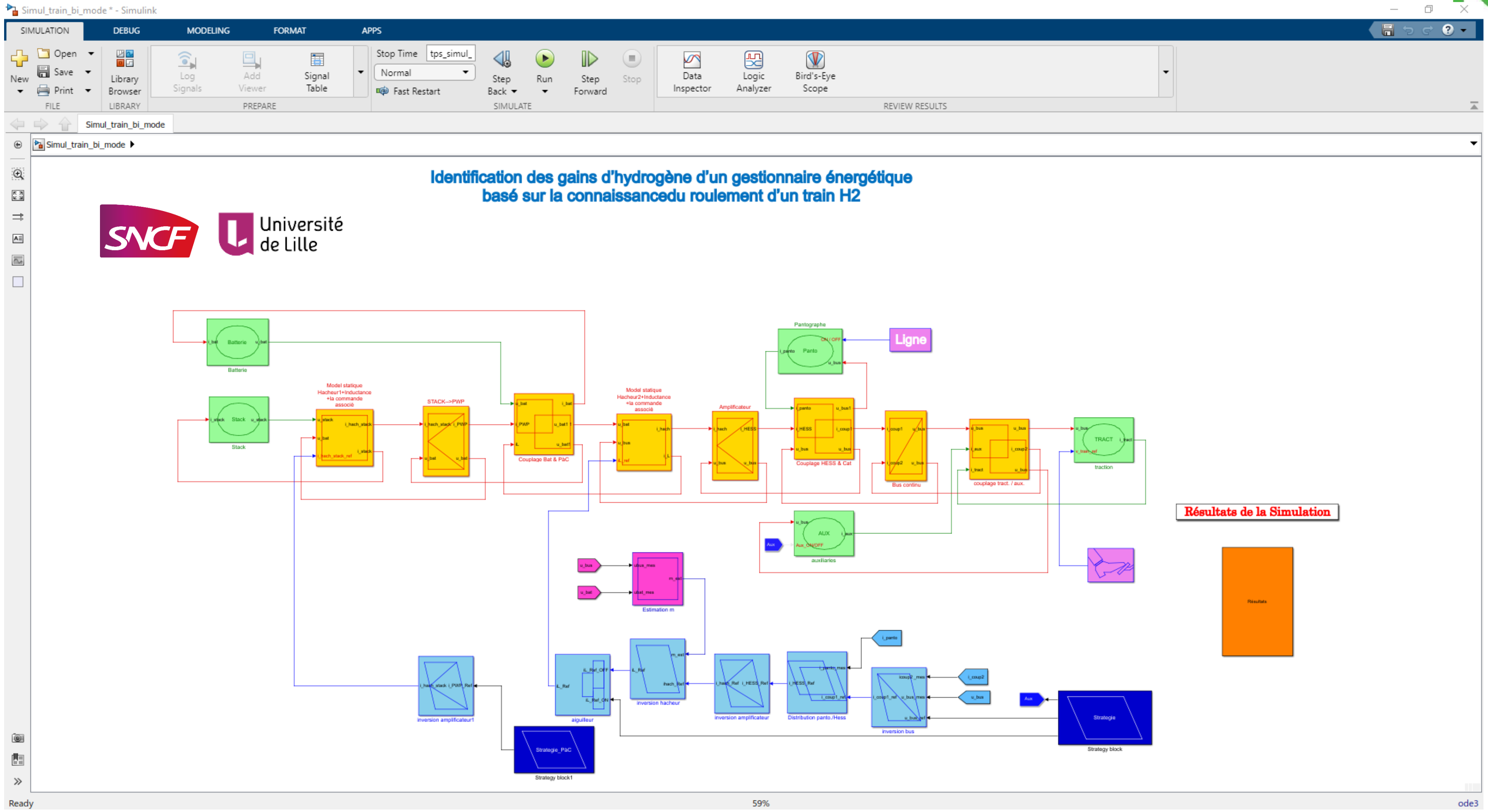
- Charge-sustaining strategy
- At the end of the track, SoCinit=SoCend
- Preserve the fuel cell from hight current dynamics



- Charge-depleting strategy

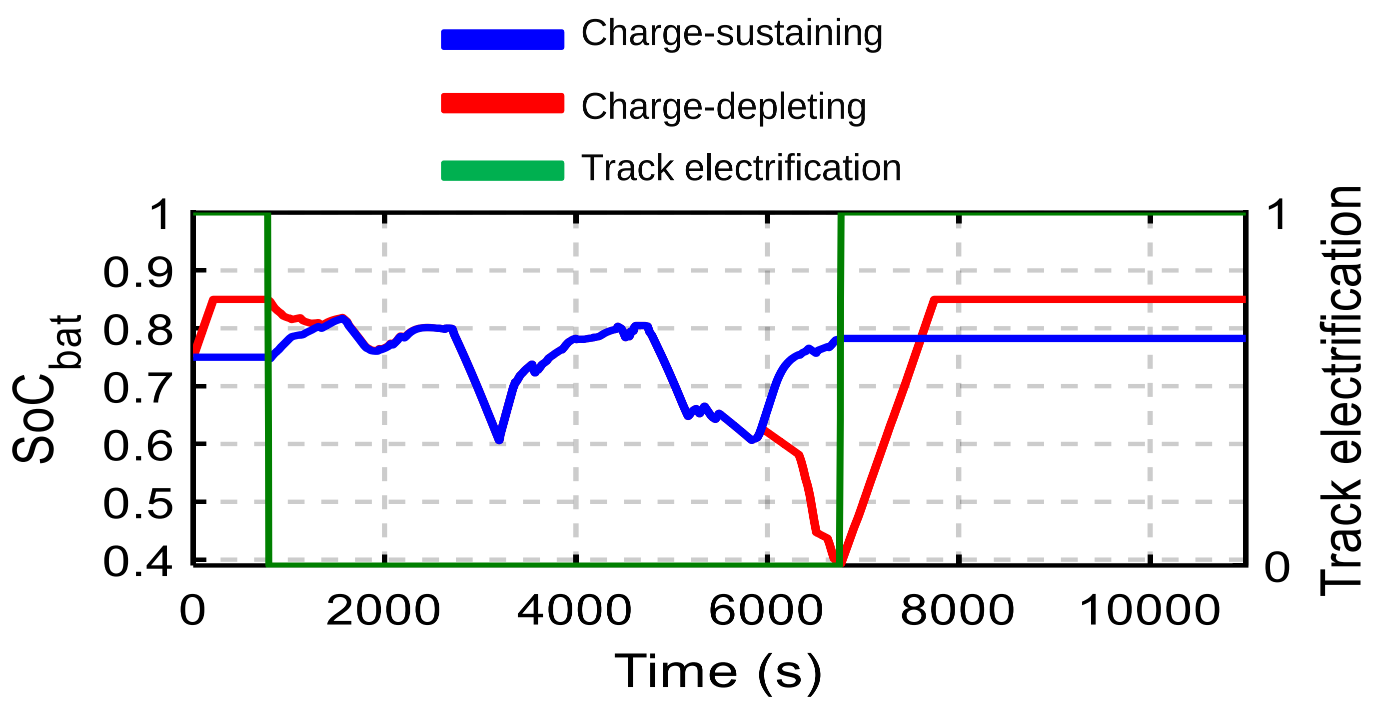


EMR, control, strategies and models have been implemented in Matlab Simulink

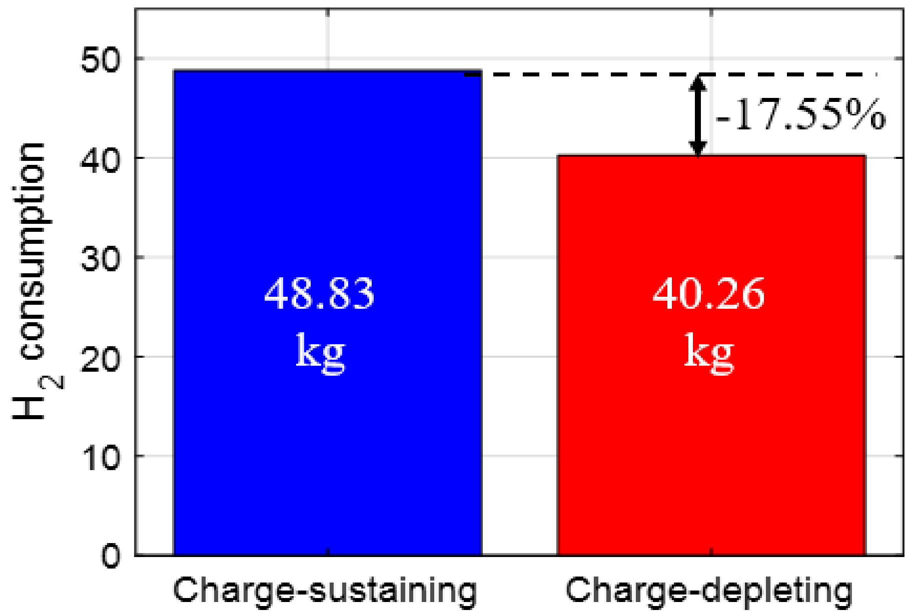


Simulations show the interest of knowing the track to consume less H2

- A real driving profile of 222 km, including 135 km of electrified lines.



8.57 kg of hydrogen are saved.



For this specific use case (track and sources sizing), the range can be increased by around 25km on this single track thanks to EMS.

Encouraging results to be consolidated by considering entire railway operation

Conclusions

- Two rule-based charge-sustaining and depleting strategies have been developed.
- A hydrogen gain of 17.55% is achieved for a real driving scenario,
- The size of the battery and the permitted depth of discharge have an important impact on hydrogen savings

Perspectives

- Investigating the benefits of adopting the charge-depleting strategy for a journey trip,
- Taking into account the economic aspect in the comparison,
- Adding other input data to target any possible energy efficiency improvements.

Feedback on the method

- How to train with EMR first time?

It is sometimes necessary to review the mathematical models to connect the elements together. A lot of work to standardize existing models needs to be done.

- How to deals with EMR library and software?

The Simulink library was used. Simulink is not always appropriate because the inputs of the “blocks” are by convention on the left and the outputs on the right, which is not the case for REM.

- What are the difficulties

Learning EMR philosophy and models. This requires long learning periods and substantial practice for complex systems. The support of the University of Lille and the L2EP was greatly appreciated.

- Interest of the PANDA methodology

Rigor and organization thanks to the standardization of models (forward). The methodology makes it possible to structure multi-domain interfaces and, with training, it saves a lot of design time or to easily understands a new system.

End of presentation

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