HIL'16 summer school
Lille, 1-2 September 2016
http://l2ep.univ-lille1.fr/hil2016/

Signal Hardware-In-the-Loop simulation of a Hybrid locomotive

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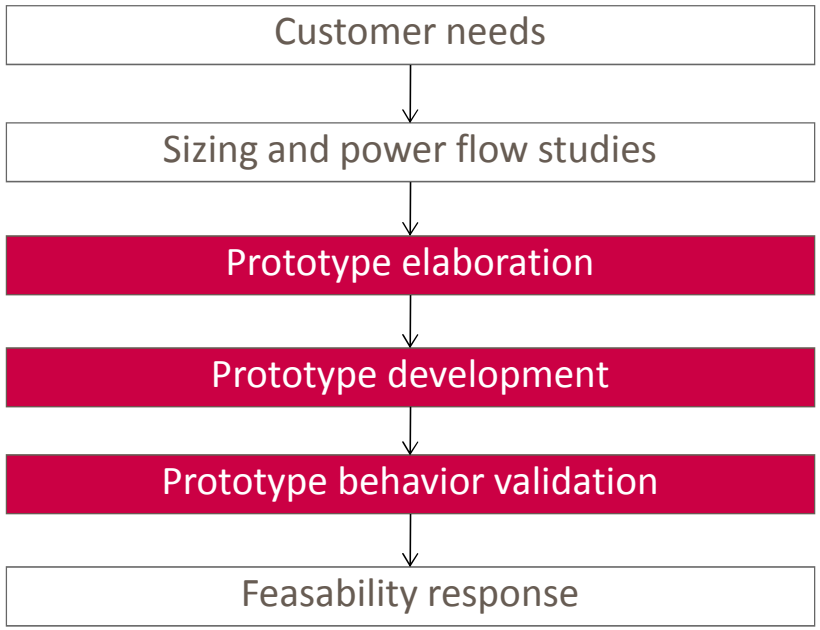
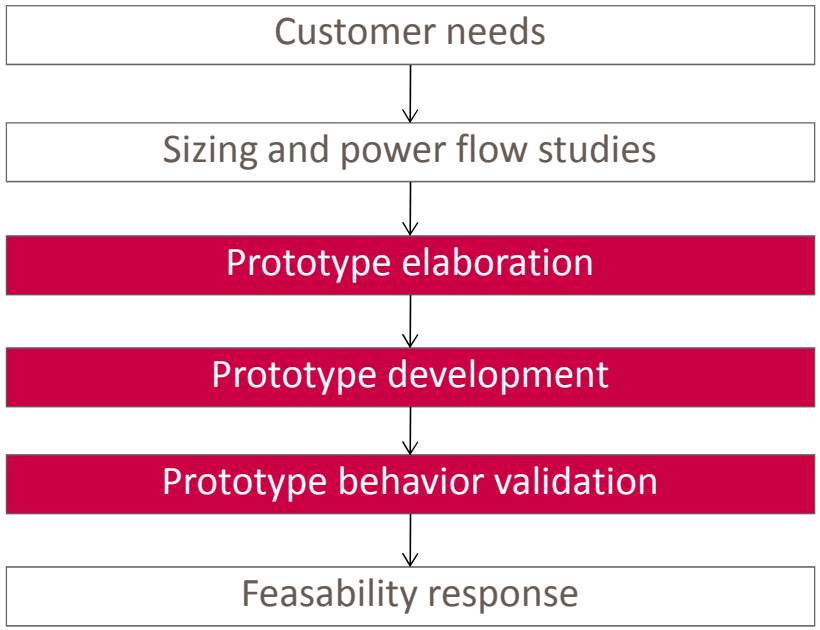
Actual approach

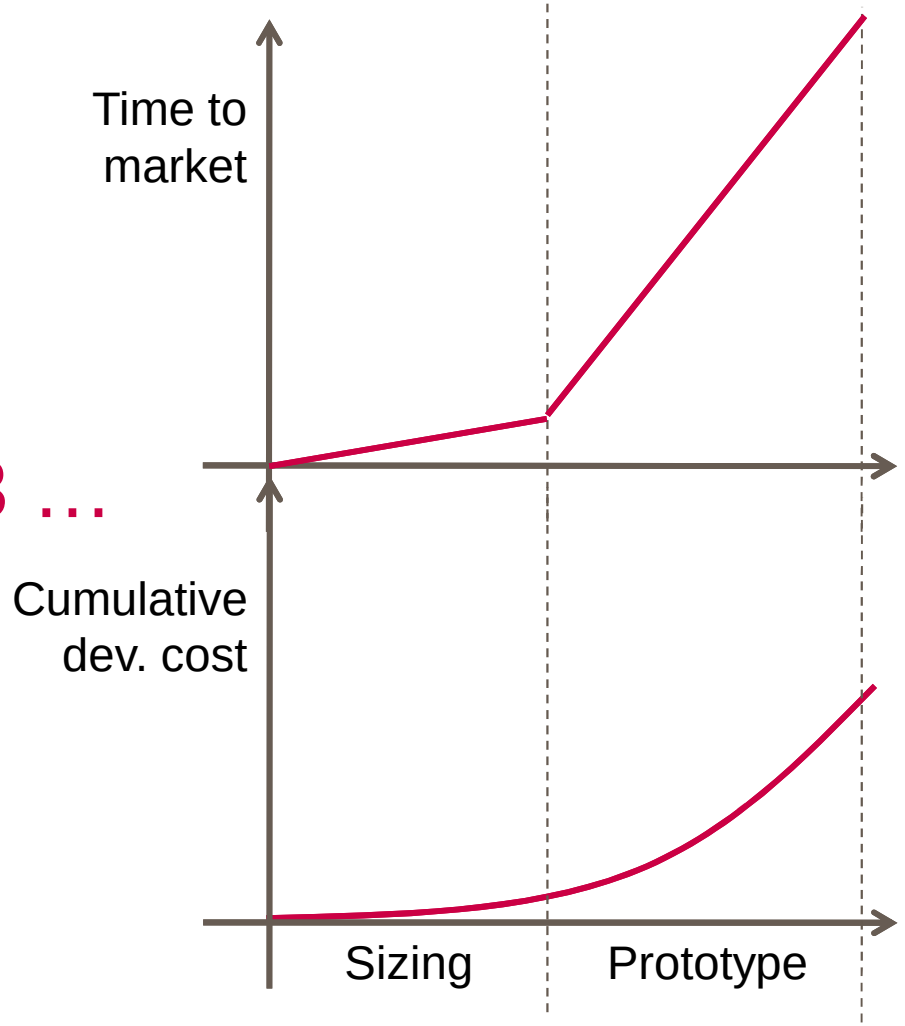


- ✓ **Direct validation** of component behavior in real time on vehicle,
- ✓ **Components homologation** (hardware),
- ✓ **All physics phenomenon** are taken into account.

Actual approach

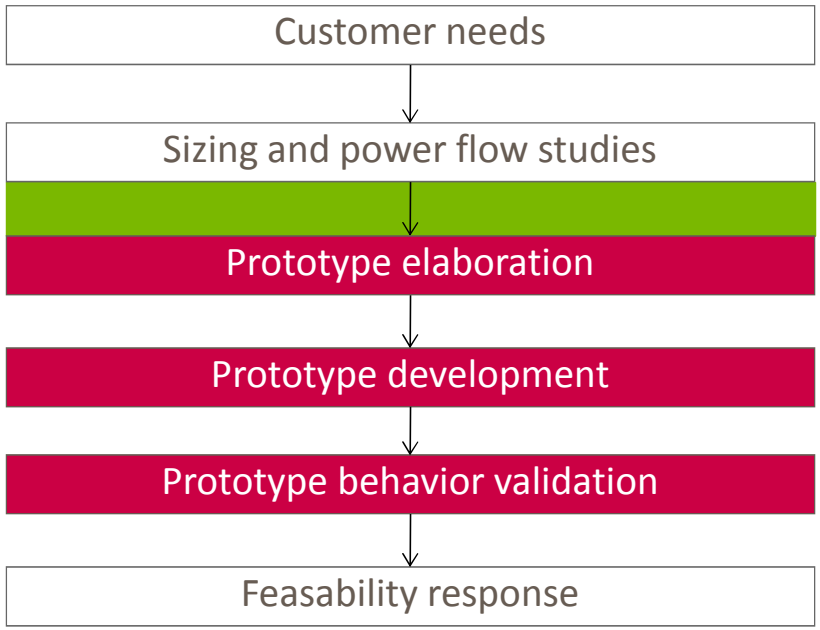


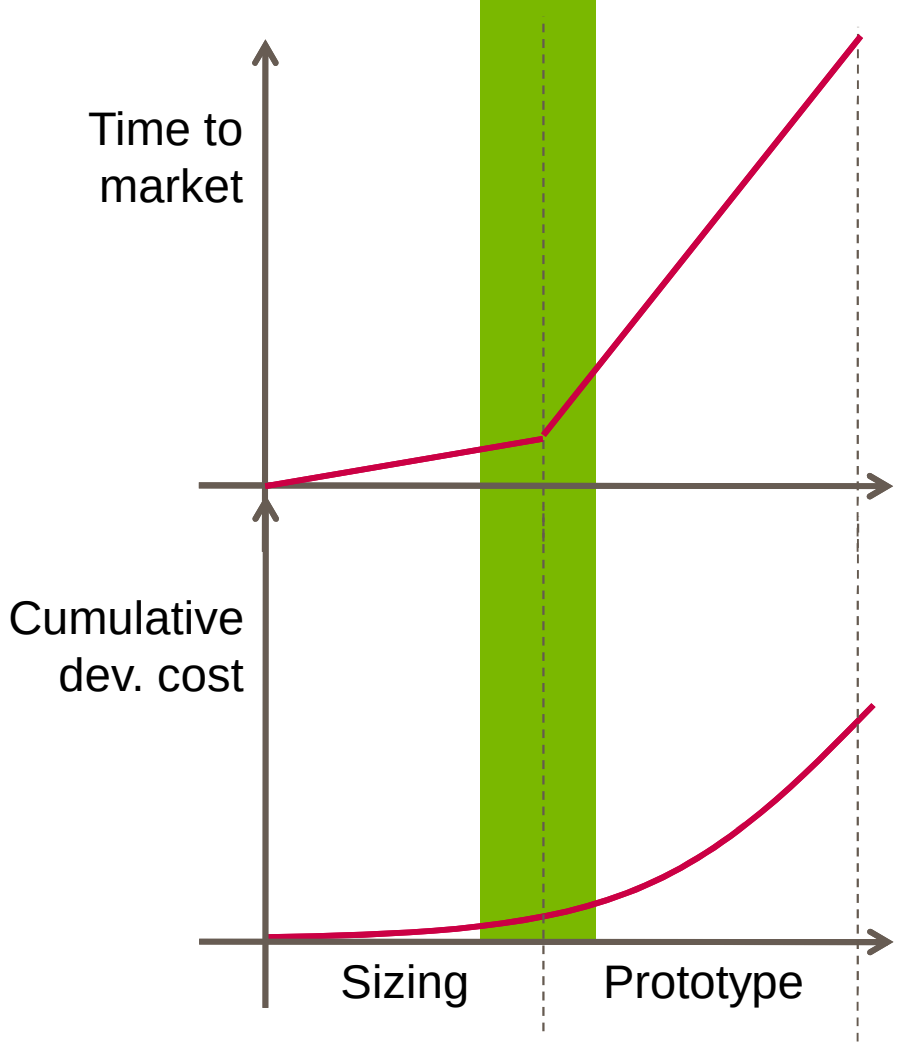
x2… x3 …



- ✓ **Complex** to develop, more than one prototype needed,
- ✓ **Time** needed,
- ✓ The development **Cost** is exponential with the time on prototype,
- ✓ A **lot of resources** are needed (prototype, staffs and tracks availability),
- ✓ **unrepeatable** tests,
- ✓ **Safety** and **fault tolerance tests** are made on-line.

Actual approach





Adding intermediary steps:

- ✓ **Reduce the time** on prototype (reduce the cost and time of development),
- ✓ **Virtual homologation** of some subsystems ahead of time.

Objective : Adding intermediaries steps

Outline

HIL simulation interest and structuring problematic

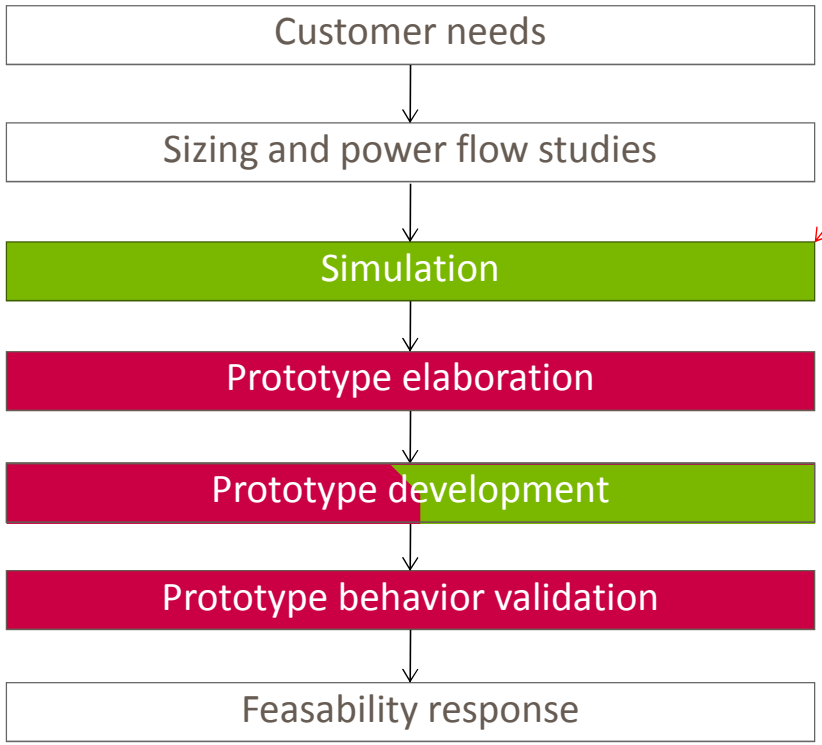
Signal HIL simulation of PLATHEE locomotive

Conclusion and outlooks

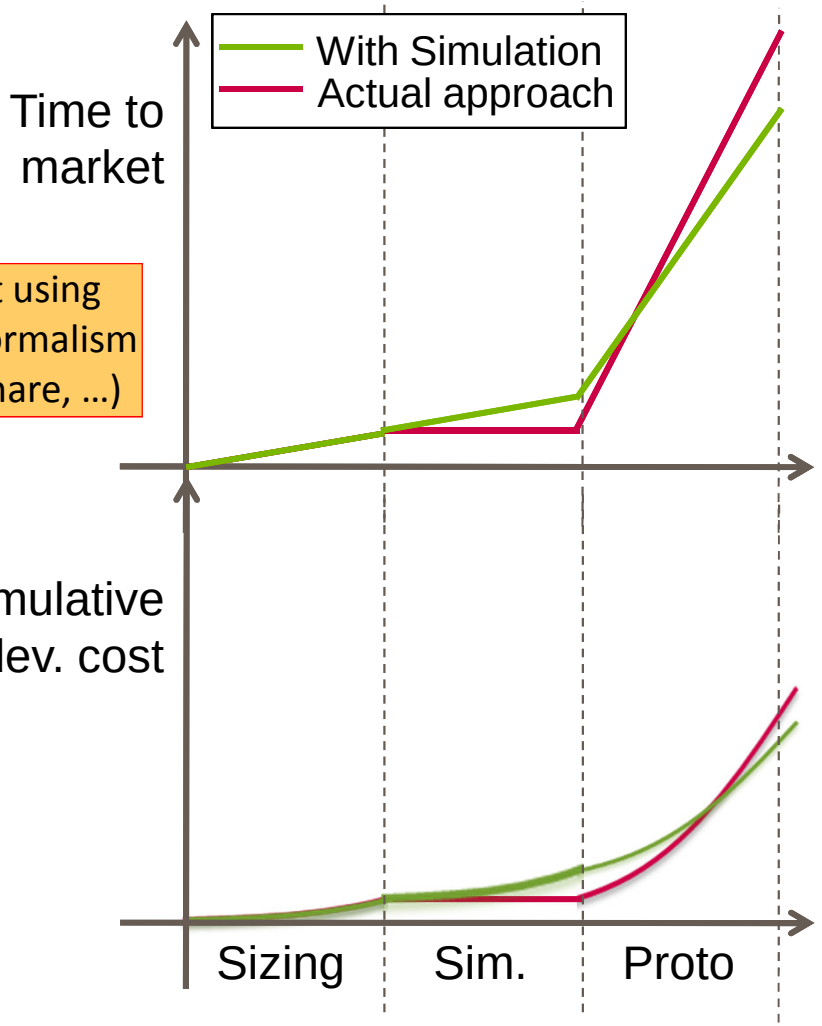
Hardware-In-the-Loop simulation :
hybrid locomotive Energy Storage System behavior tests

HIL simulation interest and structuring problematic

Adding simulation



library development using EMR (common tool, formalism unification, easy to share, …)



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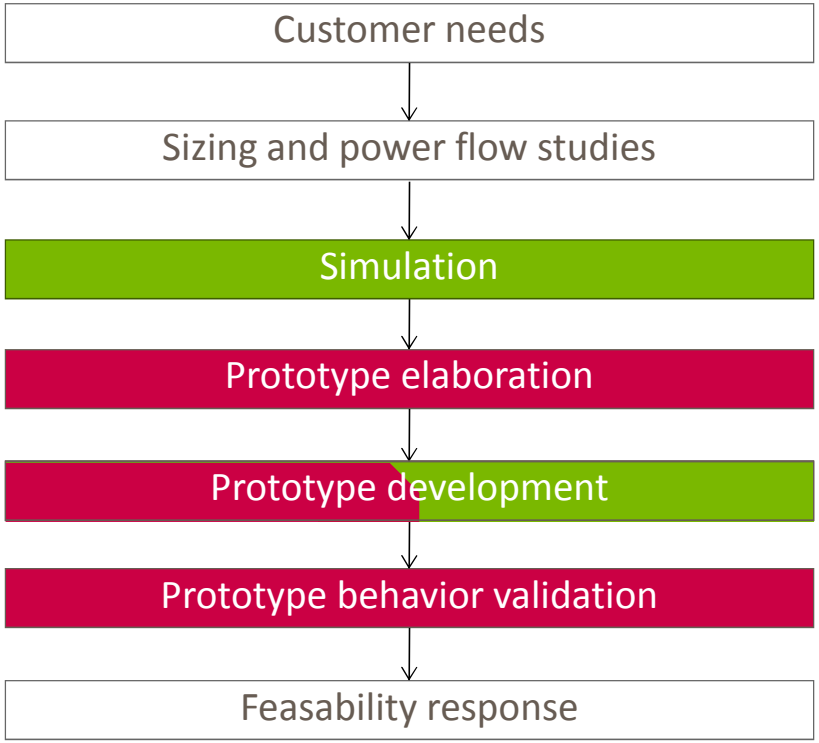
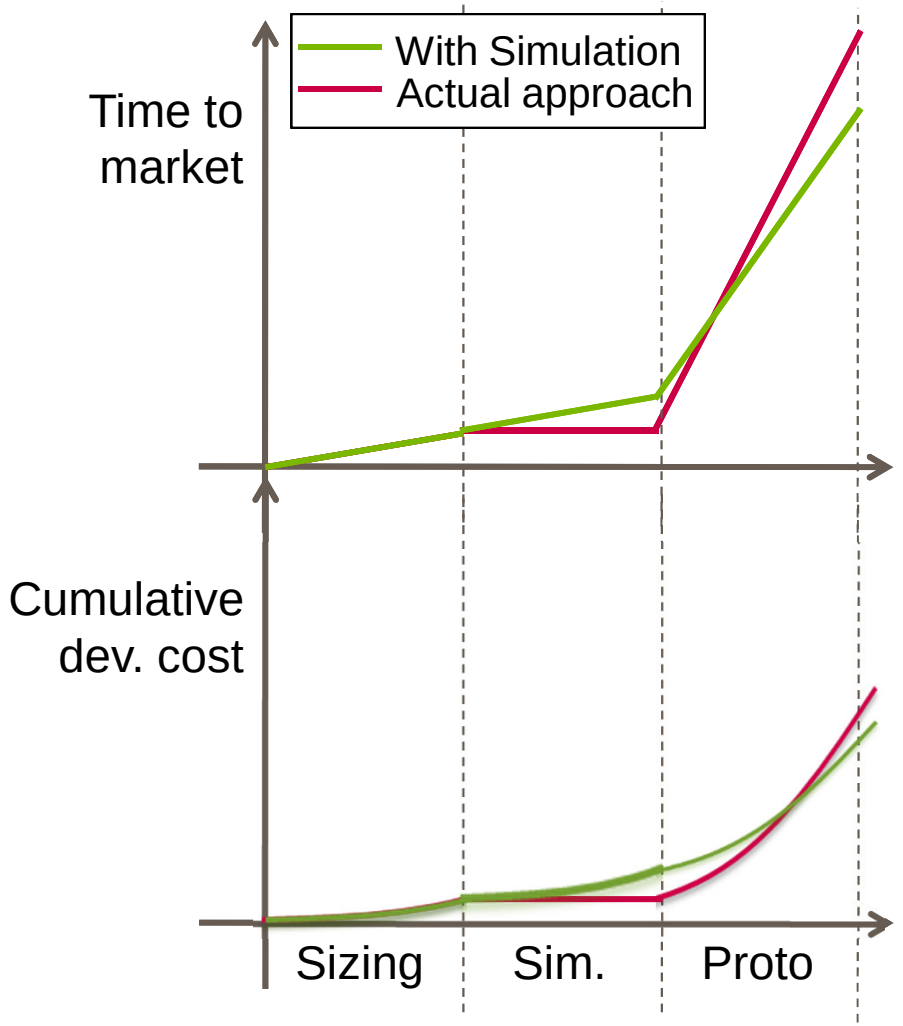
- ✓ **Prototype debugging** ahead of time (ex. control),
- ✓ **Easy to use**,
- ✓ **Quick** development,
- ✓ **Availability**,
- ✓ **Repeatable** tests.

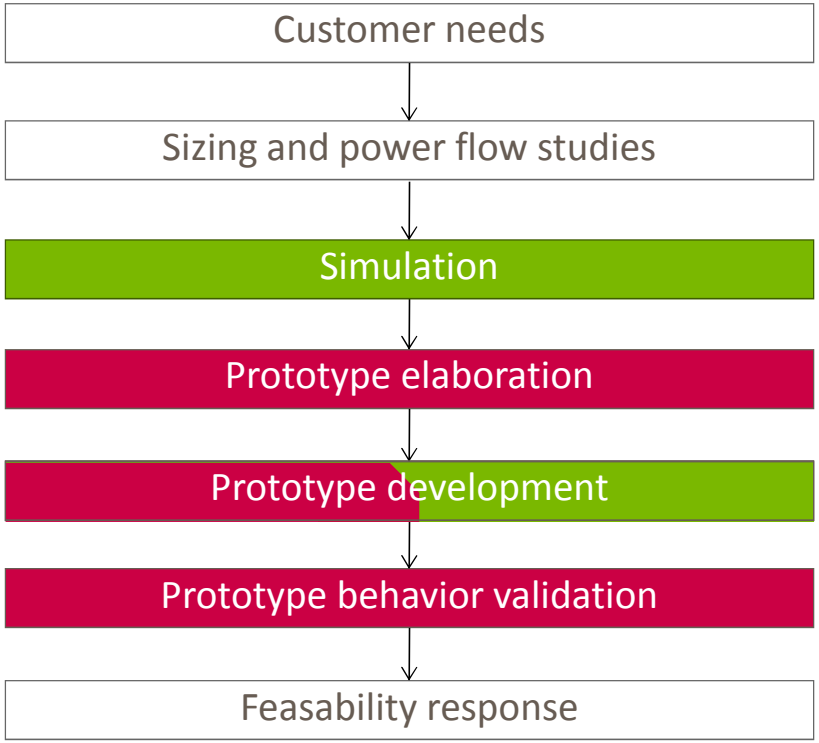
Adding simulation

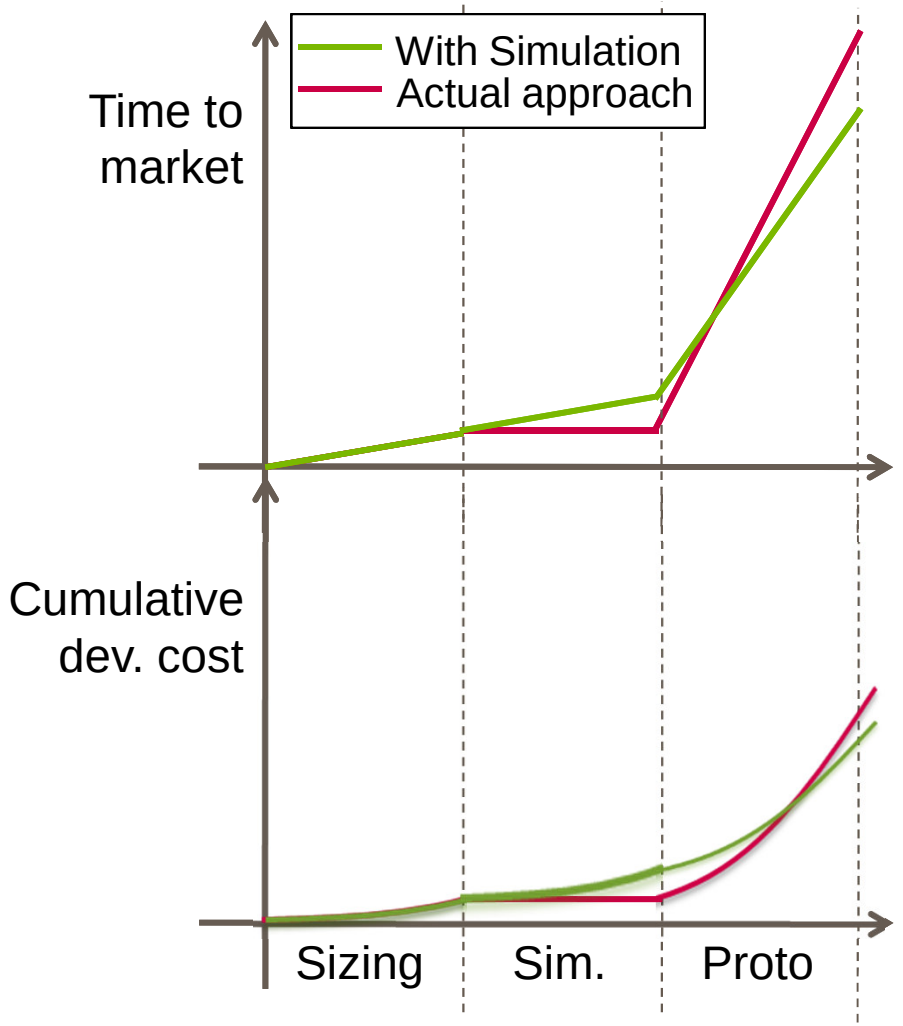




- ✓ Models **validity** range,
- ✓ virtual **homologation** complicated,
- ✓ **real time portability** of the control?

Adding simulation





Solution: « SuperModel » development?

→ *How many development time? All interaction are they taken into account?*

Power HIL simulation: Battery test example

No more model dependency :
real power part

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INTERFACE

voltage

current

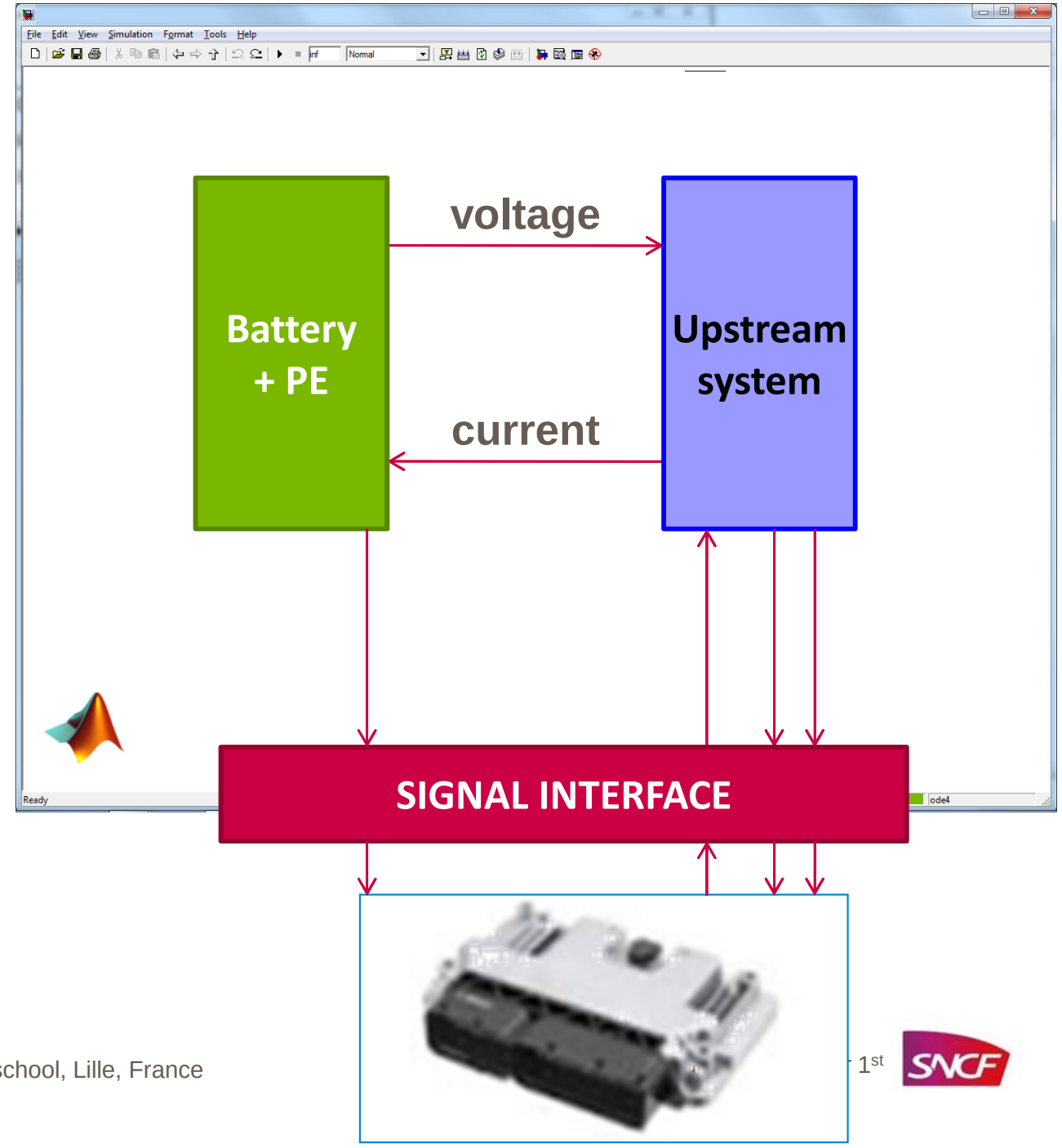
Upstream system

Control &
Energy management

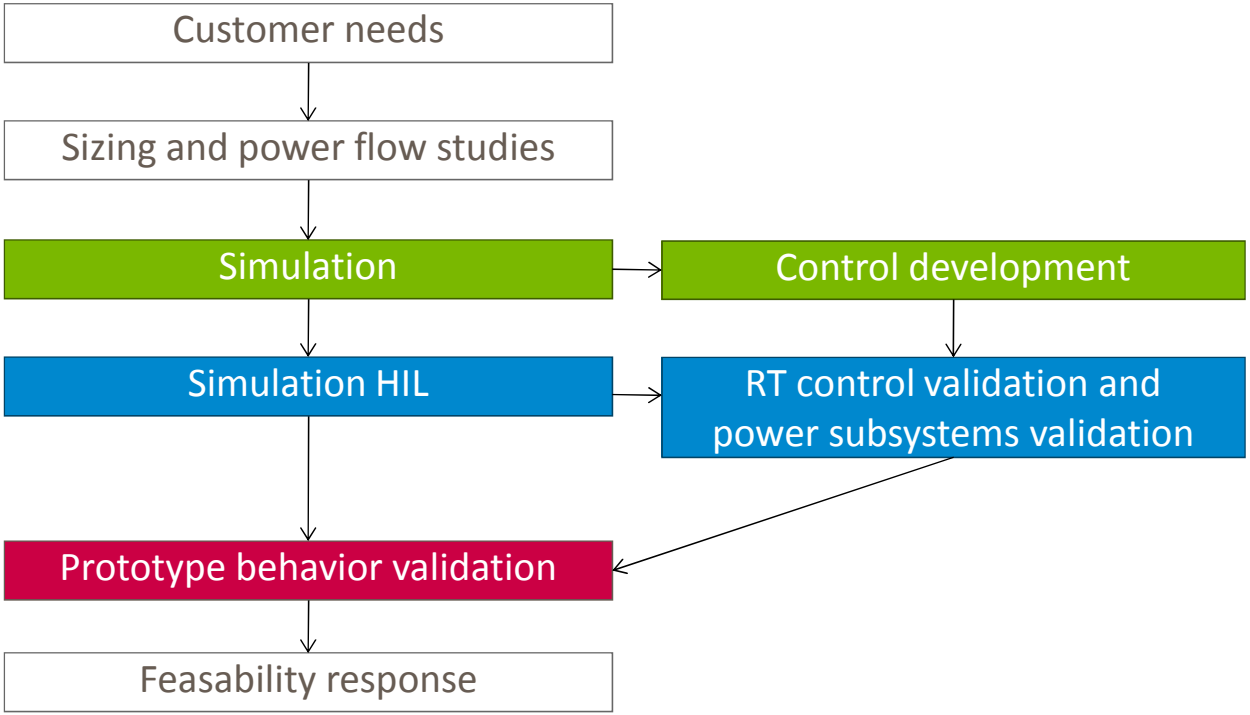
Signal HIL simulation: Energy management test

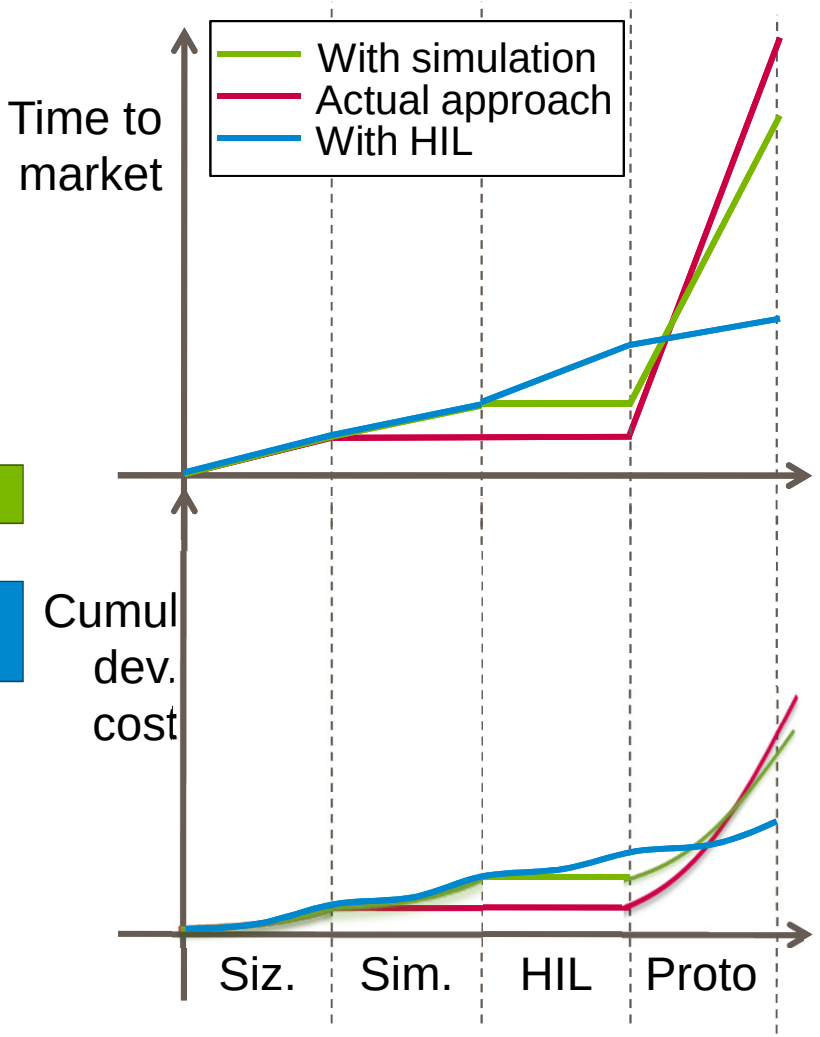
Signal HIL

- ✓Validate **new close control or energy management** system in **real time** in interaction with **emulated power systems**,
- ✓Validate **interactions between EMS and other control unit** (sensors, etc.),
- ✓Validate step time and **final control unit computation time**,
- ✓Validate **on-line EMS** behaviors,
- ✓Test EMS and close control in **fault tolerance modes.**



HIL simulation benefits





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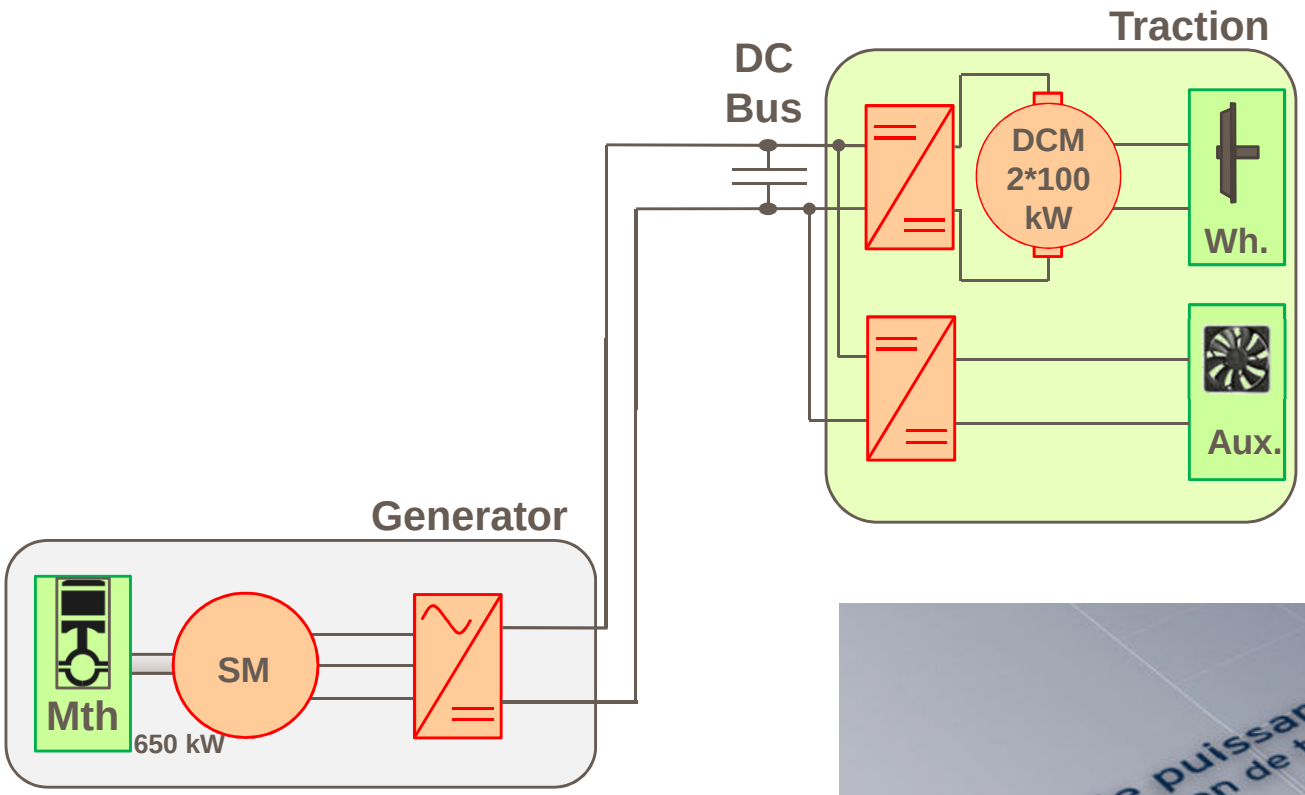
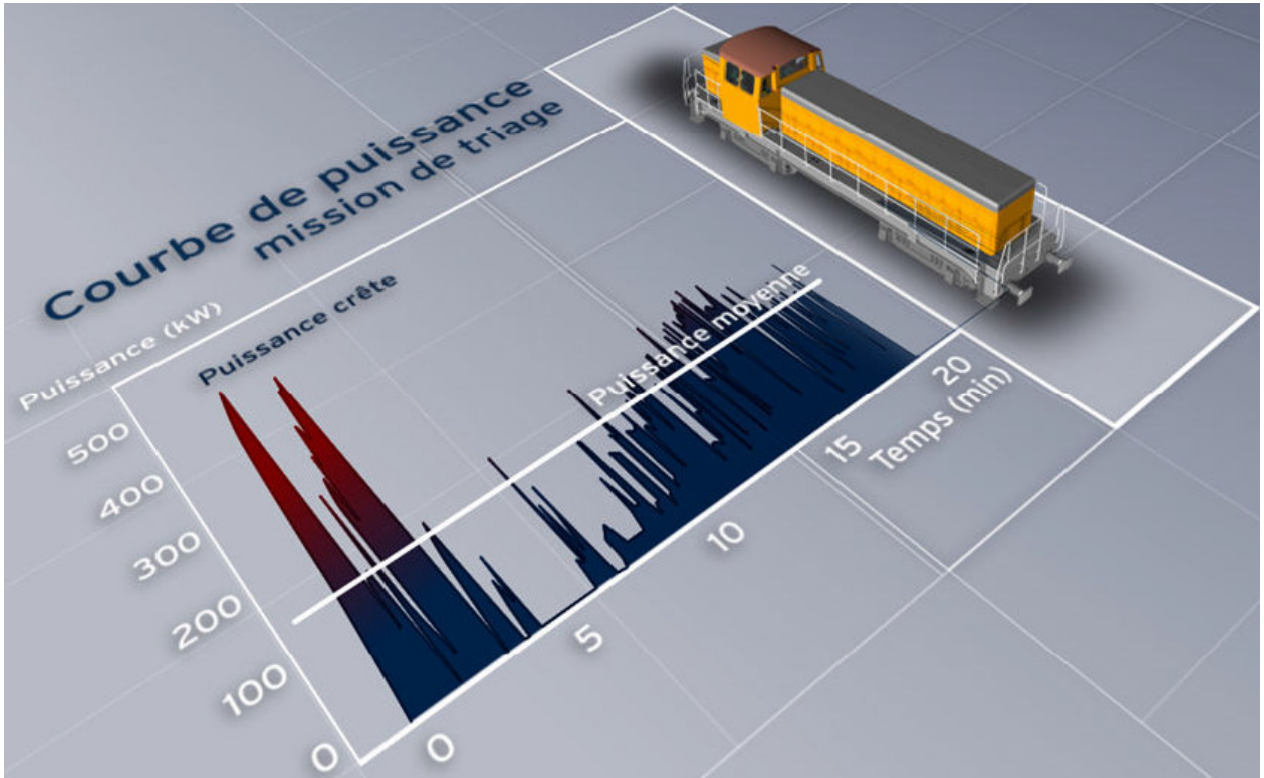
- ✓ Reduce development **time**,
- ✓ **Financial benefits** (mobilization et component deterioration),
- ✓ **Safe** et **quality** tests (fault tolerance tests),
- ✓ **Repeatable** tests,
- ✓ **Virtual homologation** available.

Hardware-In-the-Loop simulation :
hybrid locomotive Energy Storage System behavior tests

Signal HIL simulation of PLATHEE locomotive

BB63500 – Diesel Electric locomotive

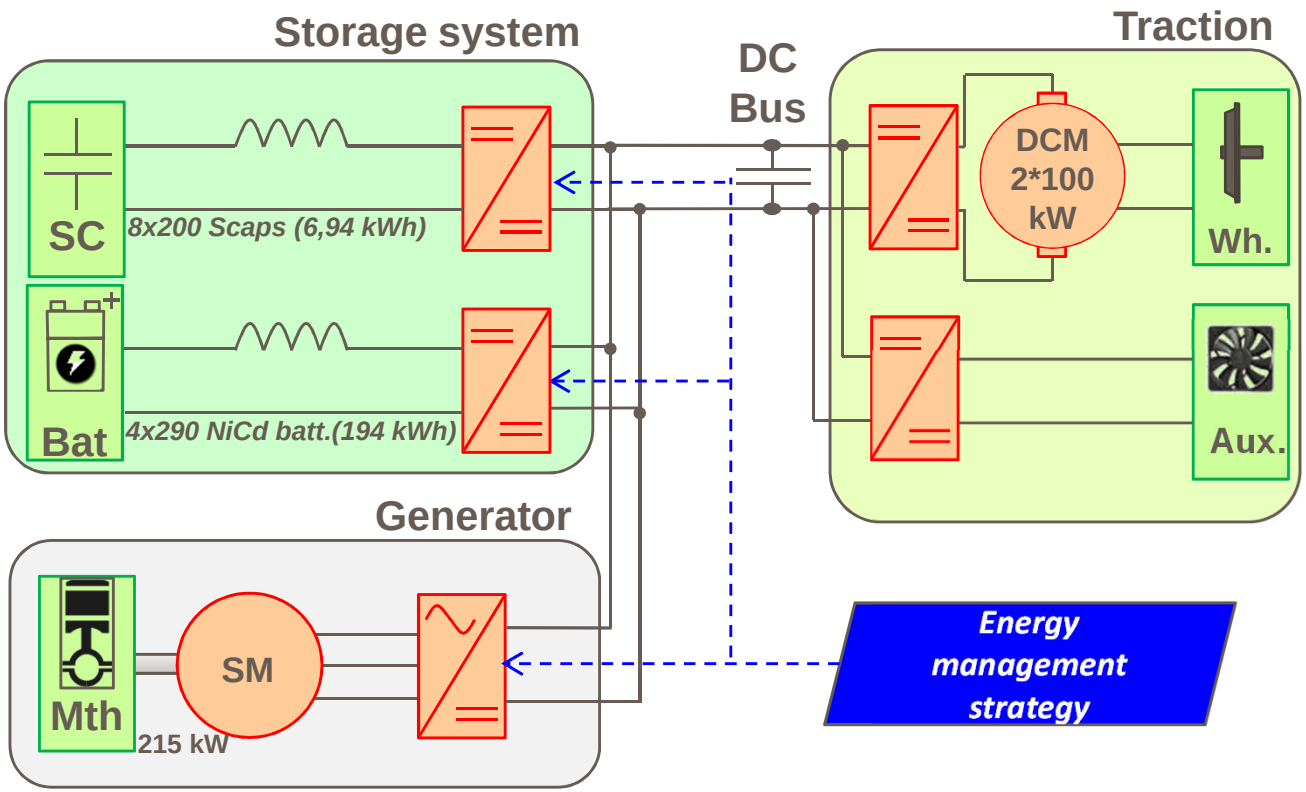


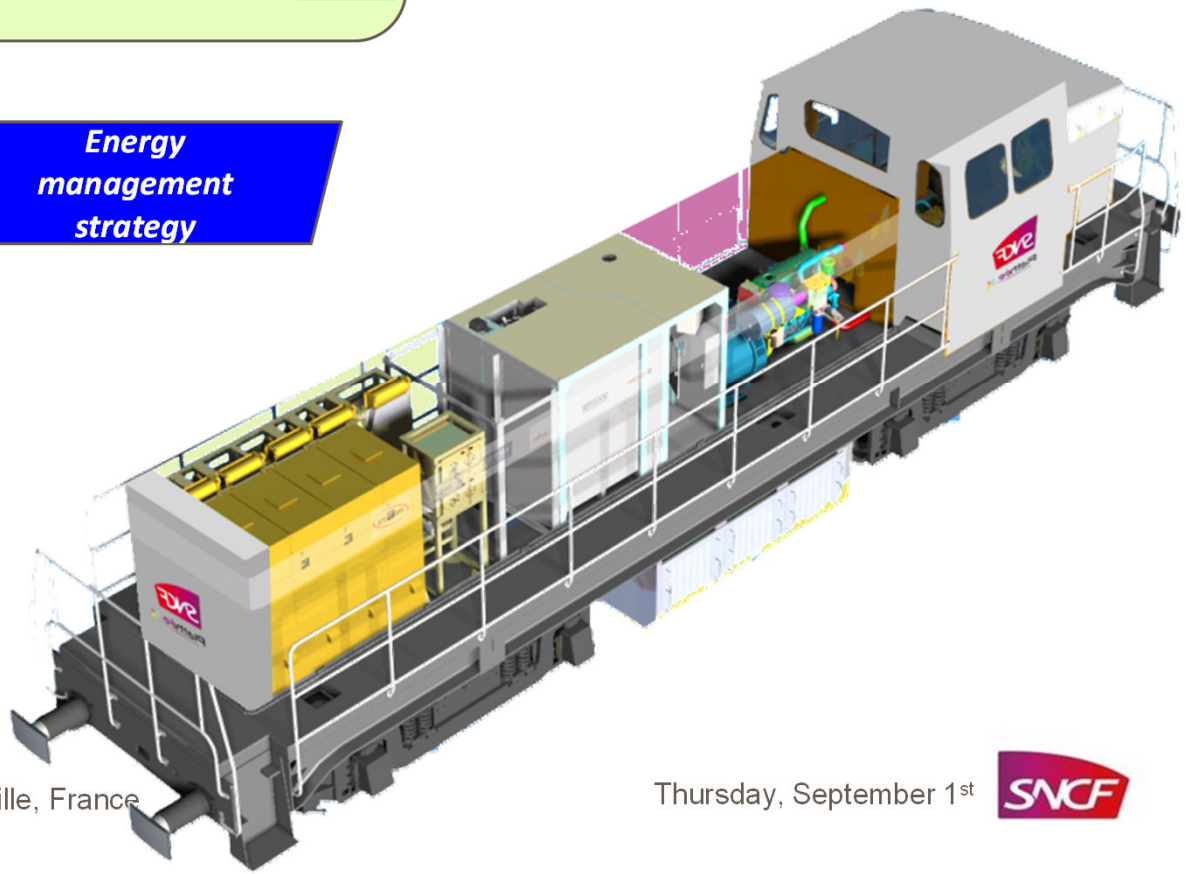


Drawbacks :

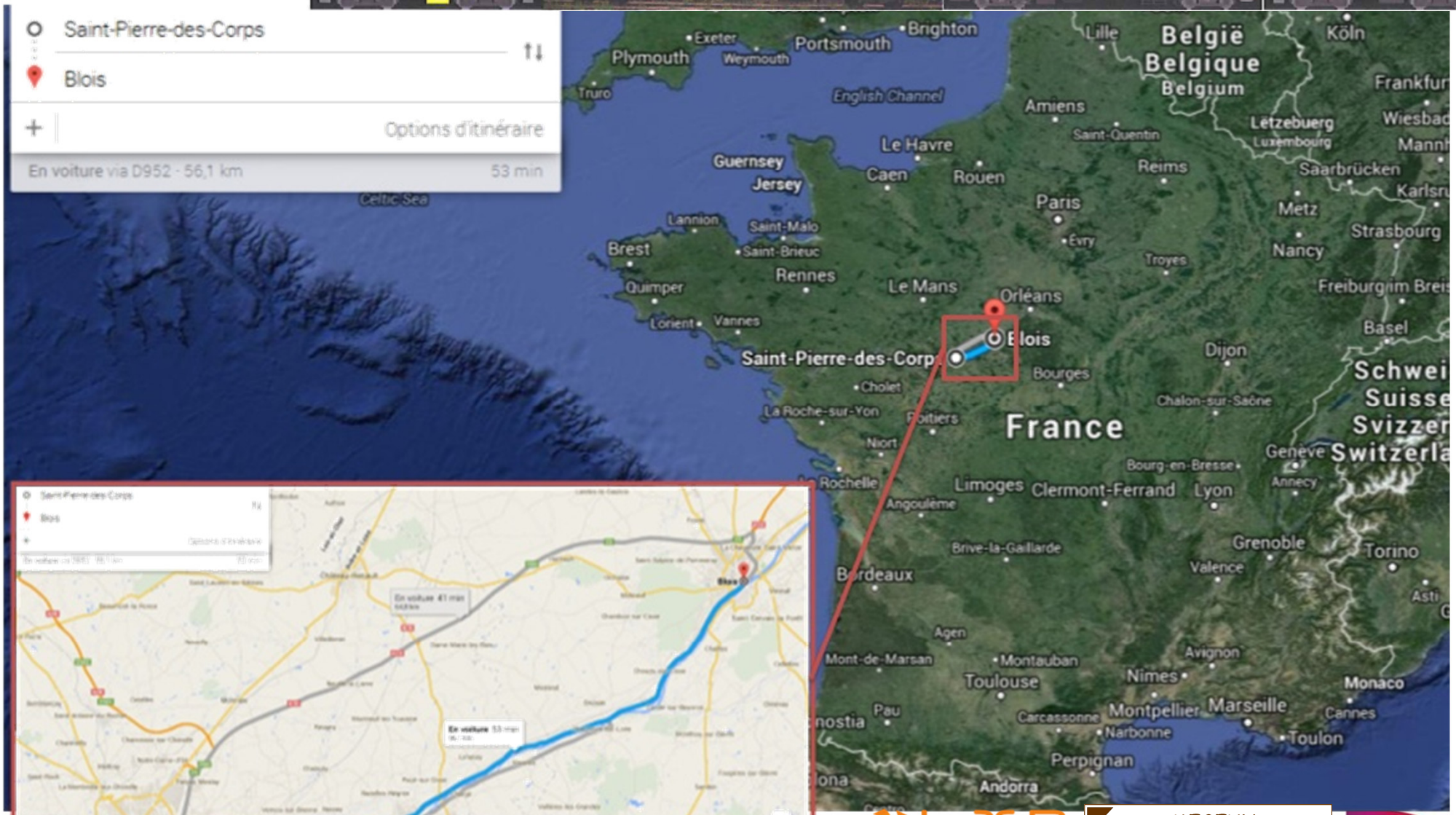
- **No energetic storage** for traction or auxiliaries,
- **Oversized** generator for shunting operation,
- Diesel engine is **uninterrupted** (Auxilairies, etc.),
- Diesel engine is not always in its **maximal efficiency point**.

Plathée – Hybrid locomotive





PLATHEE energetic benefits validation



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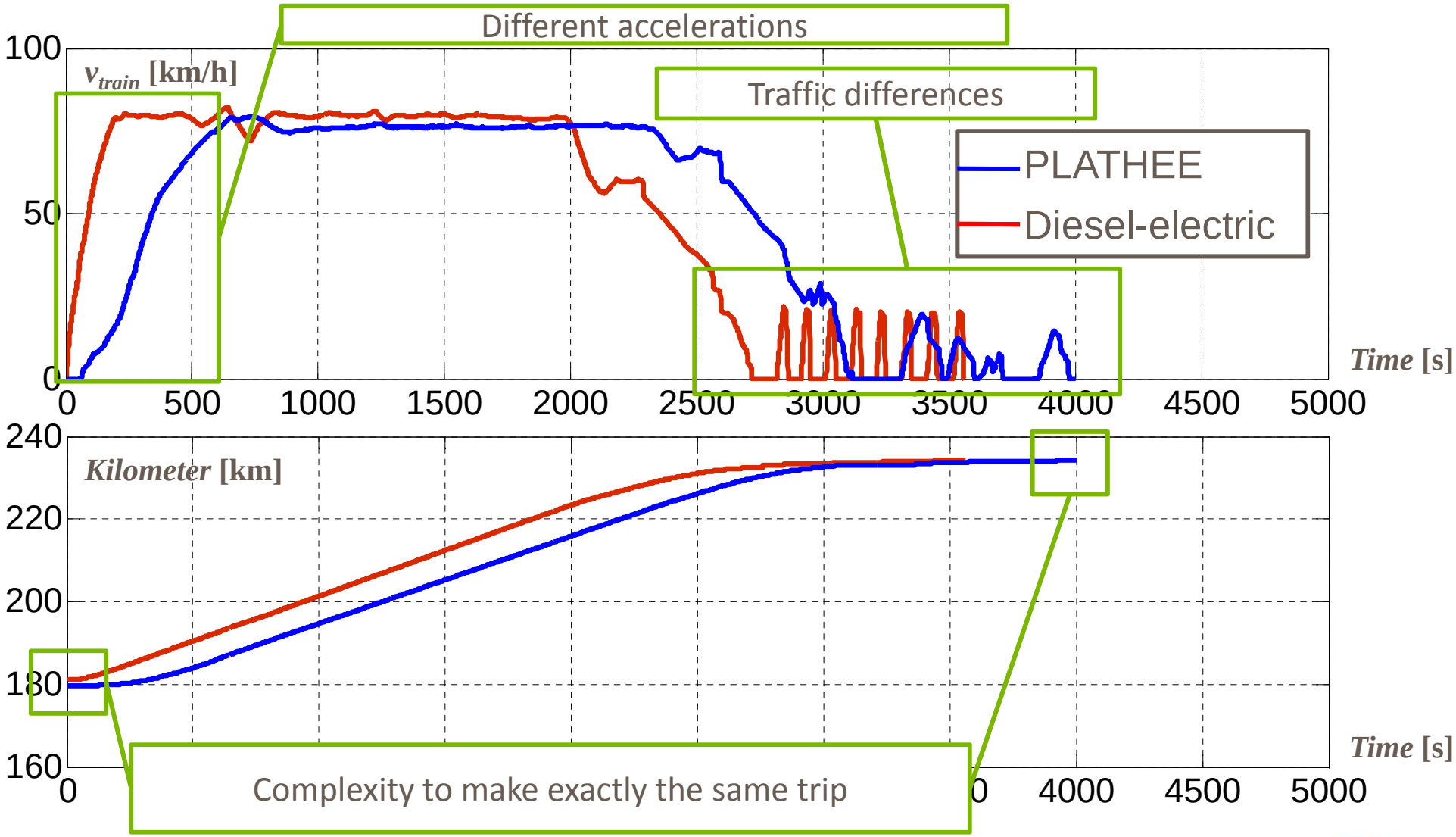
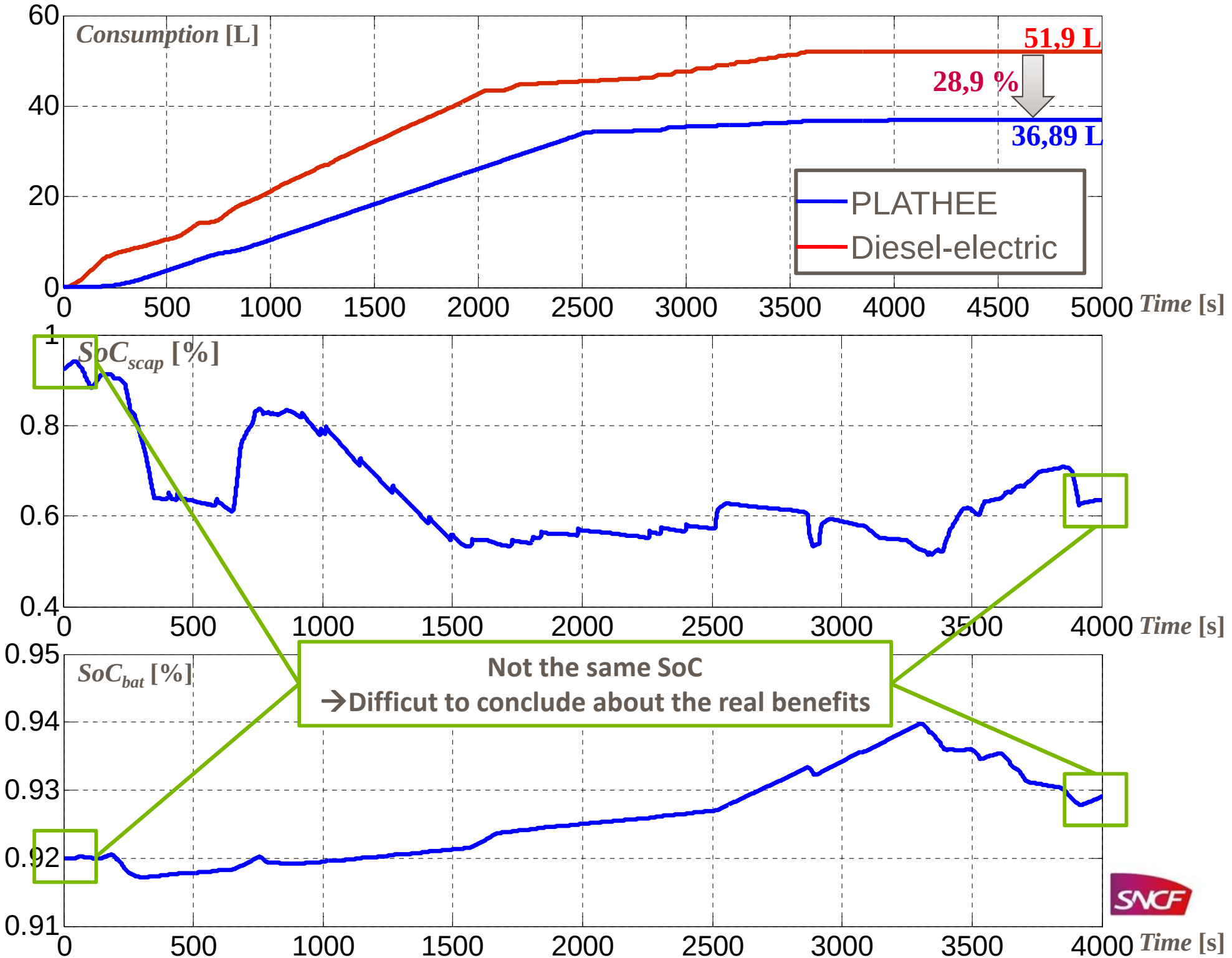
MEGEVH
French network on HEV's

SNCF

PLATHEE energetic benefits validation



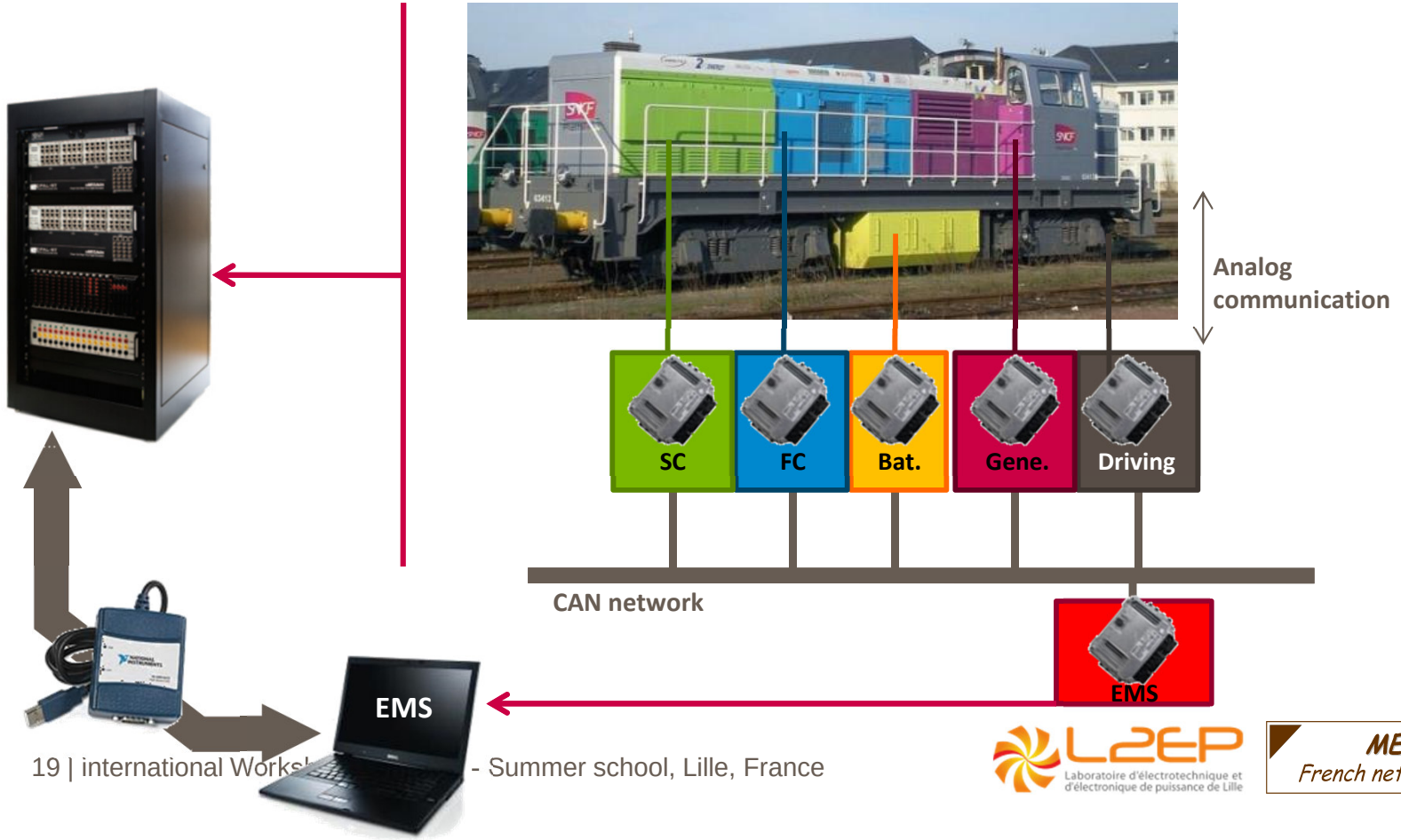

Consumption [L]
51,9 L
28,9 %
36,89 L
PLATHEE
Diesel-electric
Time [s]
SoC_scap [%]
Time [s]
SoC_bat [%]
Not the same SoC
→Difficut to conclude about the real benefits
Time [s]

PLATHEE – Hybrid locomotive

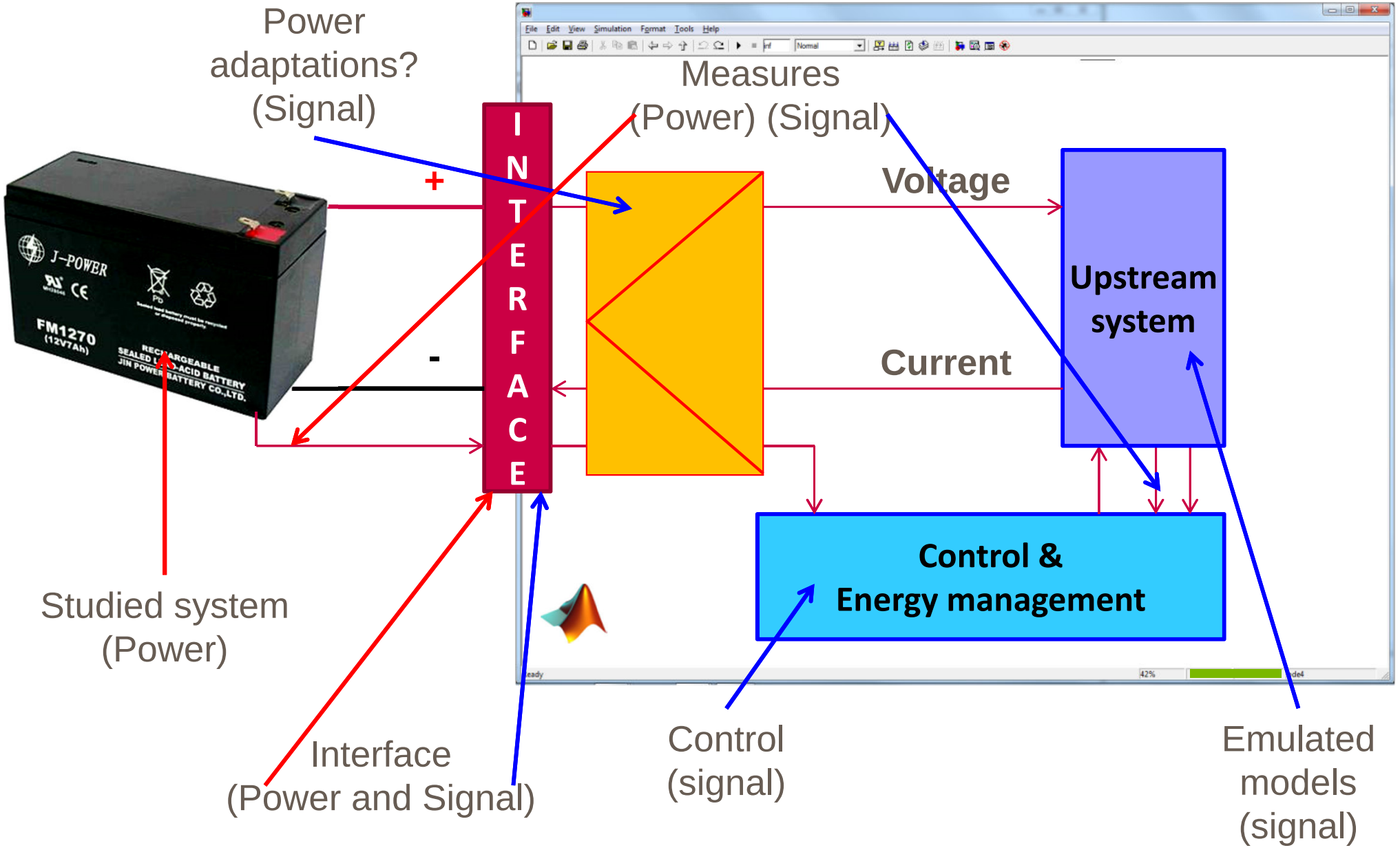
- **Energetic benefits are difficult to achieve** directly on prototype,
- EMS development on prototype is **expensive**.

Objectives :

Develop a **real time test bench** to test Energy management strategies using **on-experimental results** validated models



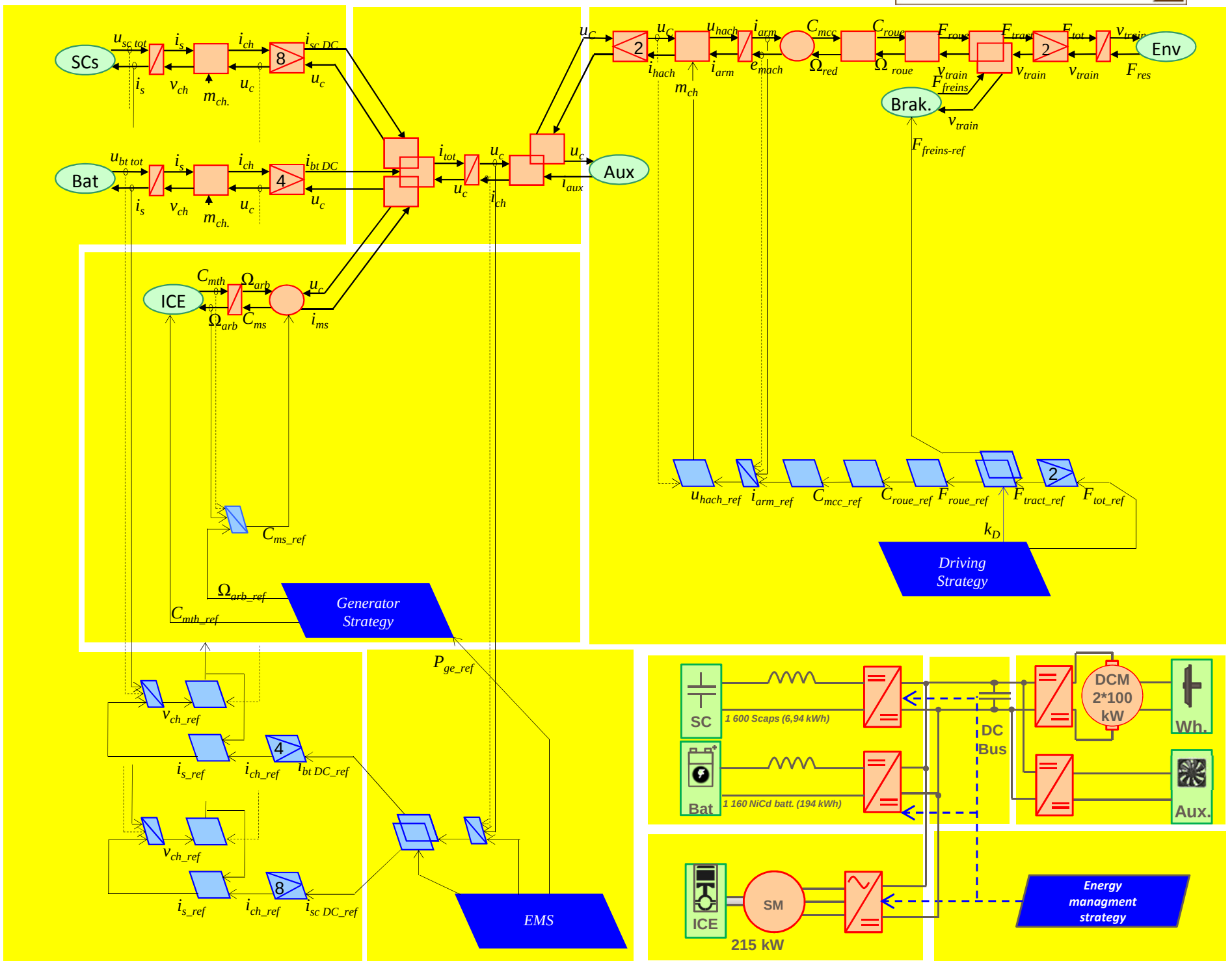
Structuring needs problematic of a Power HILs



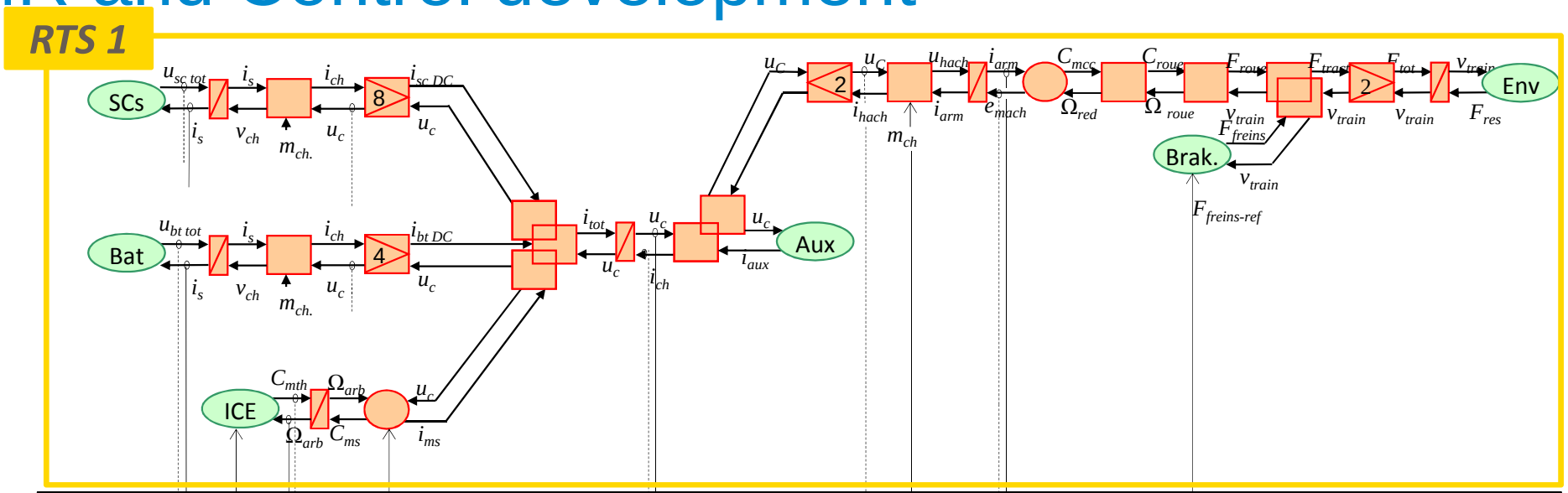
Can EMR helps to structure the different parts of a HIL simulation?

EMR and Control development

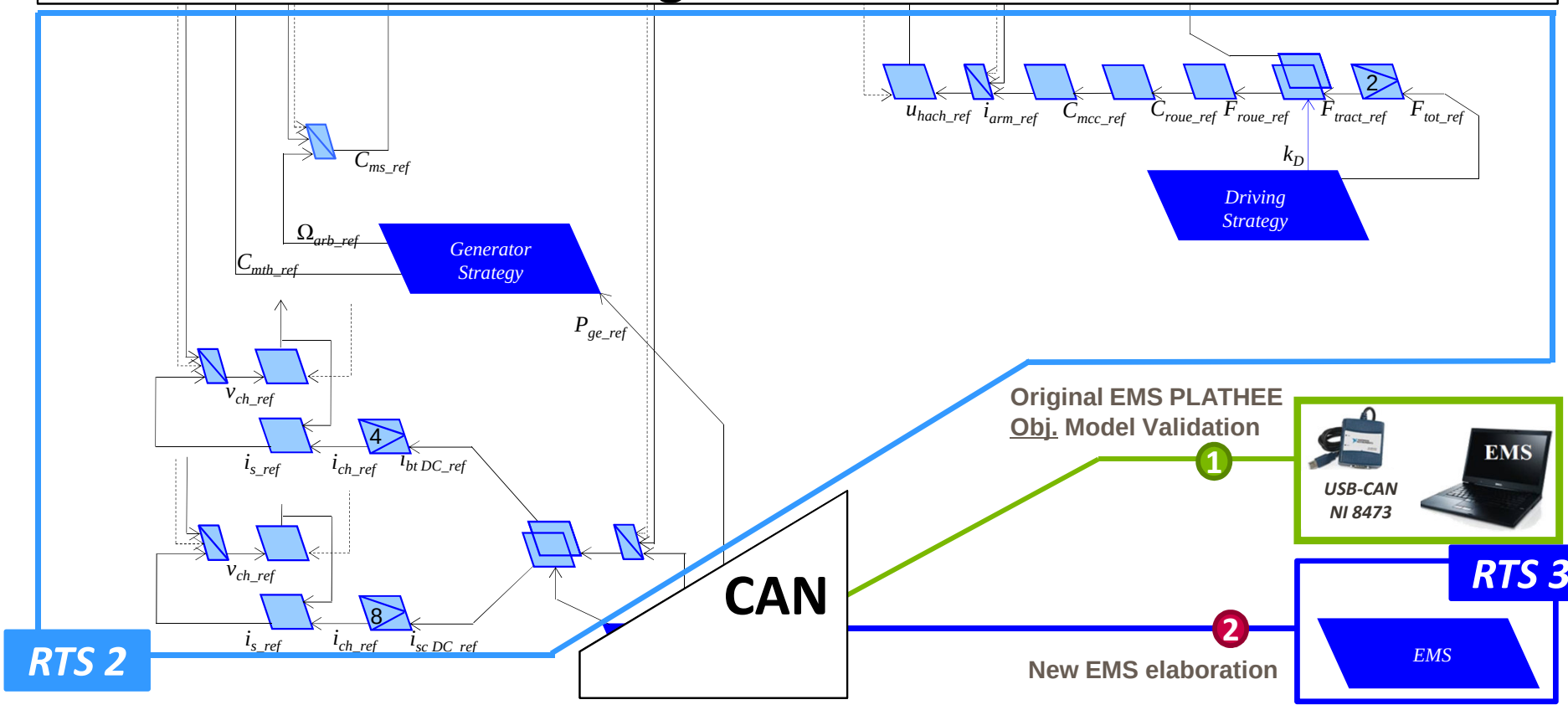
MEGEVH
French network on HEV's



EMR and Control development



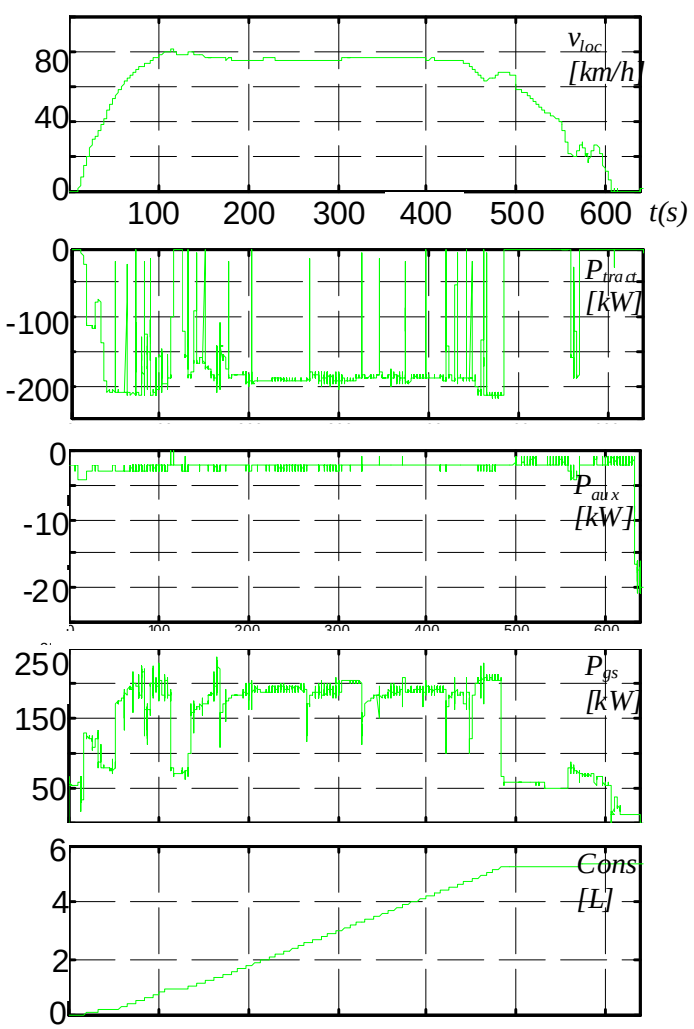
Analog communication

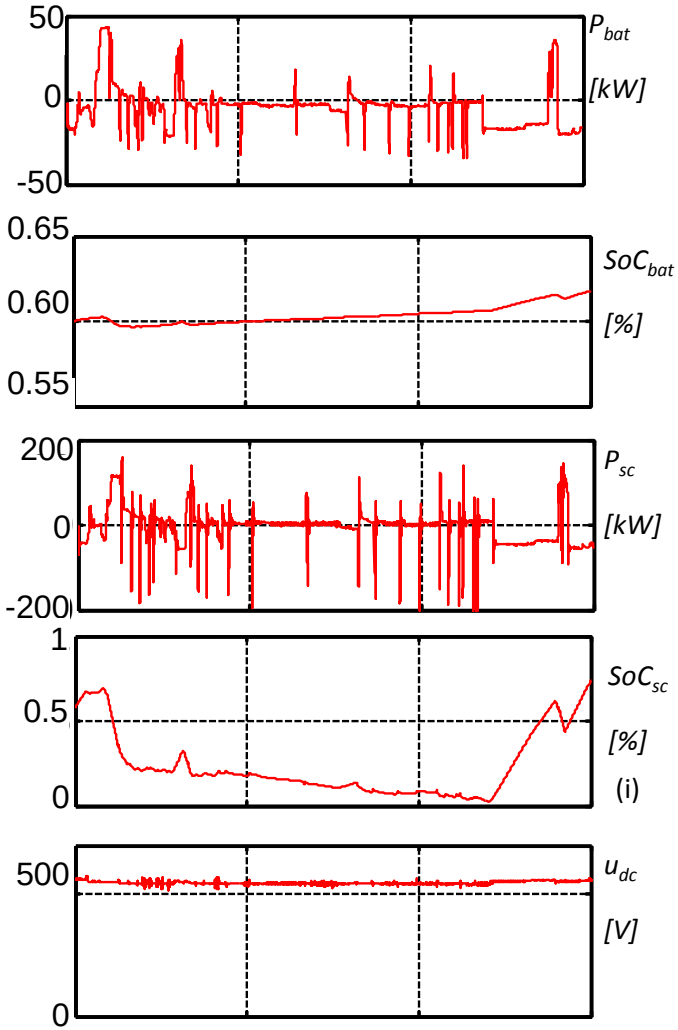


Experimental setup and results

1 – Same EMS than Prototype :

→ Models validation



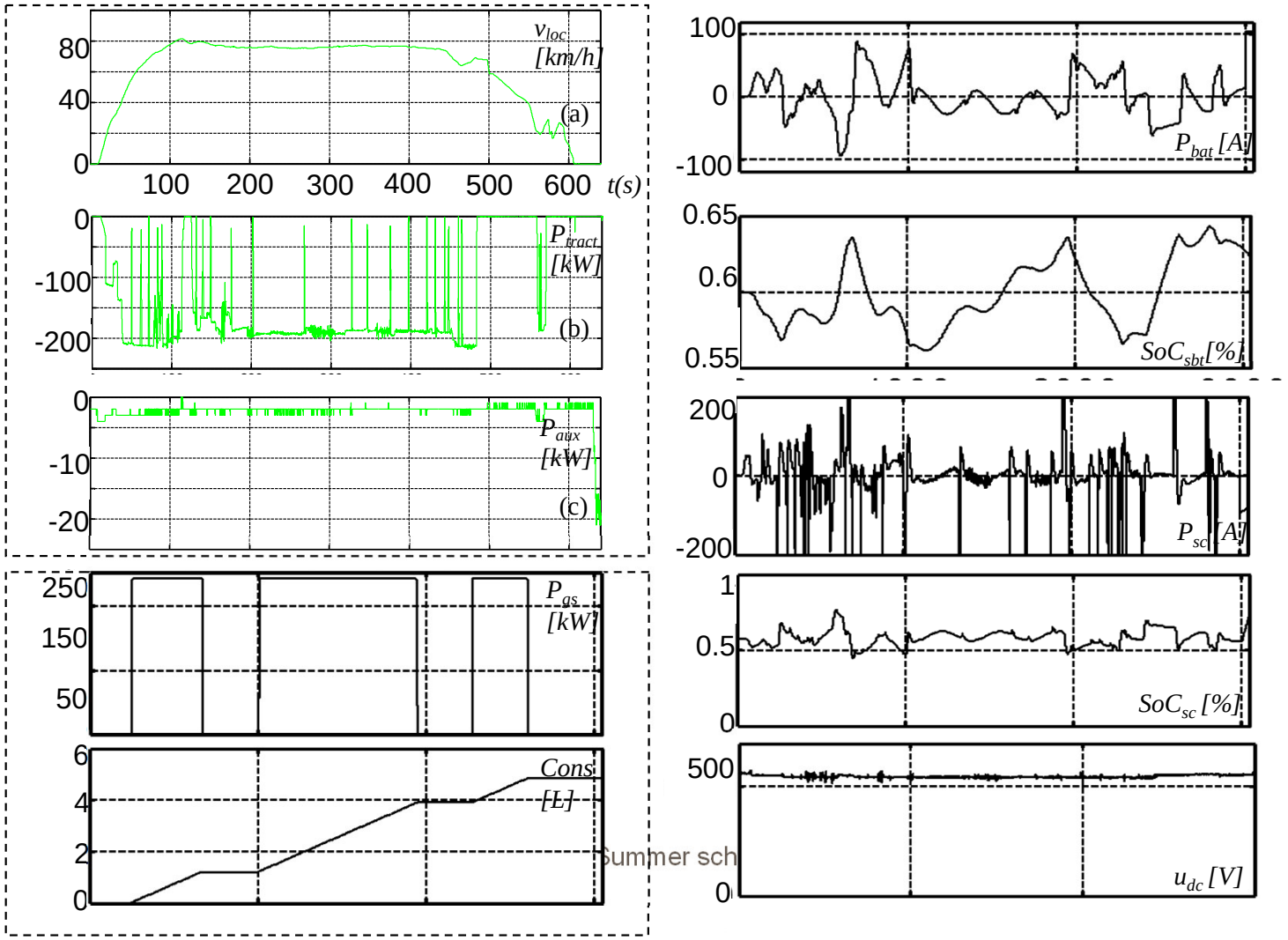


	Exp. Meas.	S-HIL Results	Error [%]
SoC_{BT} [%]	61.75	61.45	**0.5**
SoC_{SC} [%]	73.5	77.3	**4.9**
Fuel [L]	27.7	26.3	**5.3**

Experimental setup and results

2 – New EMS and studies outlooks :

→ Fair strategies comparison (maintenance, component behavior, fuel, …)



Hardware-In-the-Loop simulation :
hybrid locomotive Energy Storage System behavior tests

Conclusion and outlooks

Conclusion & outlooks

EMR as a structuring tool :

- Such a complex system and experiment needs methodology : EMR,
- Integral causality allows to use description and control part in real time.

Signal HIL simulation

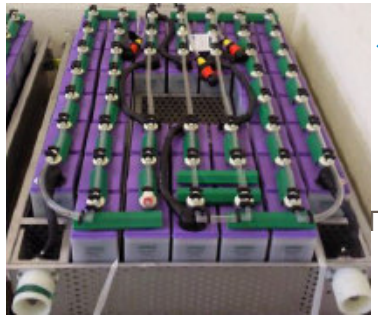
- Reduce the cost and time to market of new developments,
- Do not required any prototype component,
- Quick development and adjustment possibility,
- Model validation in real time using original EMS and experimental measurements:

	Experimental measures	S-HIL Results	Error [%]
SoC_{BAT} [%]	61.75	61.45	**0.5**
SoC_{SC} [%]	73.5	77.3	**4.9**
Fuel [L]	27.7	26.3	**5.3**

PLATHEE Supercapacitors→

Outlooks

- fault tolerance tests and control robustness,
- Power HIL simulation,
- Full scale implementation on prototype.



←PLATHEE NiCd Batteries

Thanks for your attention !

For more questions, comments or needs :

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