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

Presentation based on the PhD of T. Letrouvé (2013)

« CONTROL STRUCTURE FROM THE SIMULATION TO THE PROTOTYPE OF A DOUBLE PARALLEL HEV USING ENERGETIC MACROSCOPIC REPRESENTATION »

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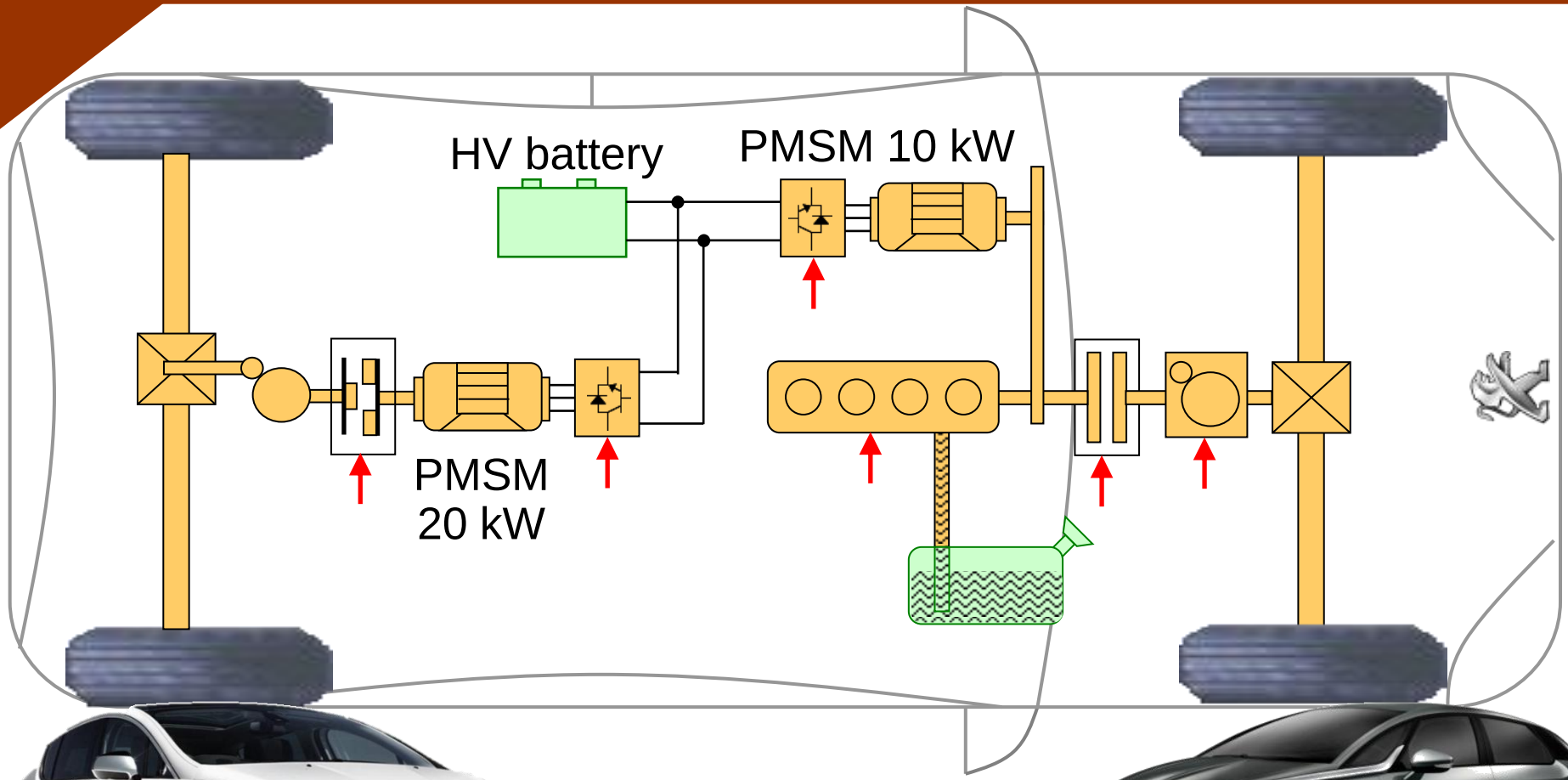
Double parallel architecture: HYbrid4



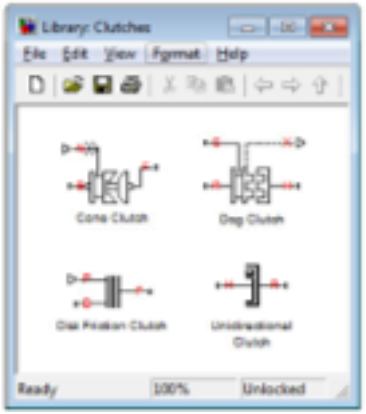
How to organize the control and manage the energy?

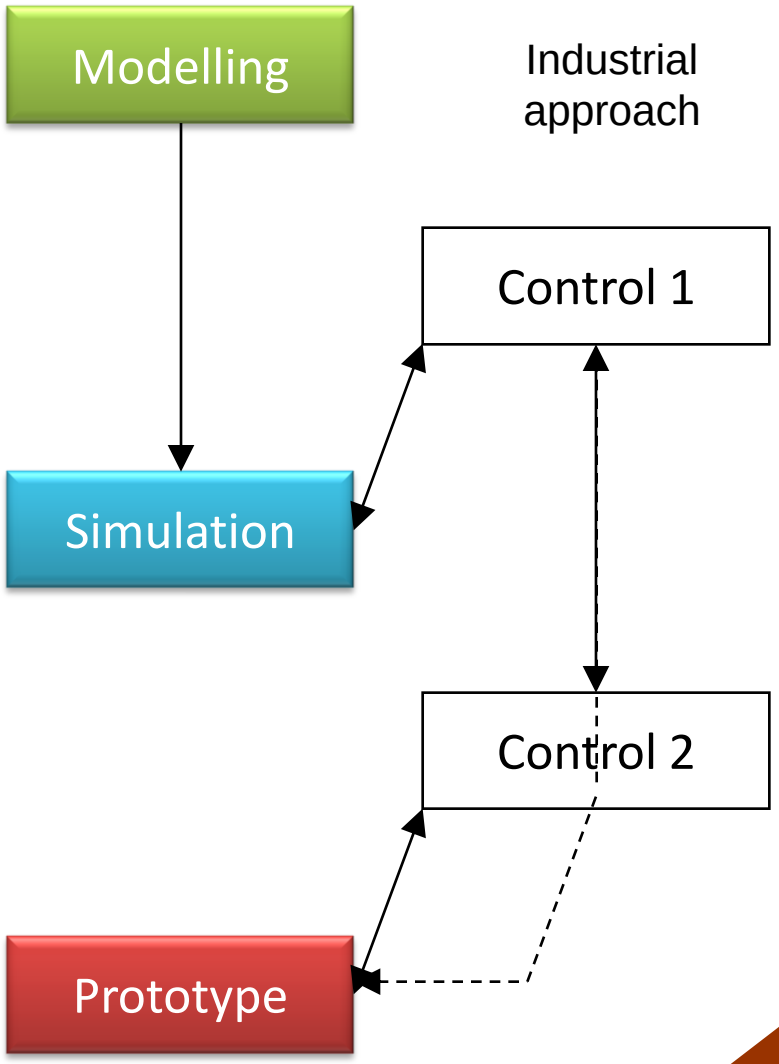
Industrial approach of the control

Structural simulation tools

- Dymola
- AMEsim
- SimDriveline
- AUTONOMIE
- ADVISOR

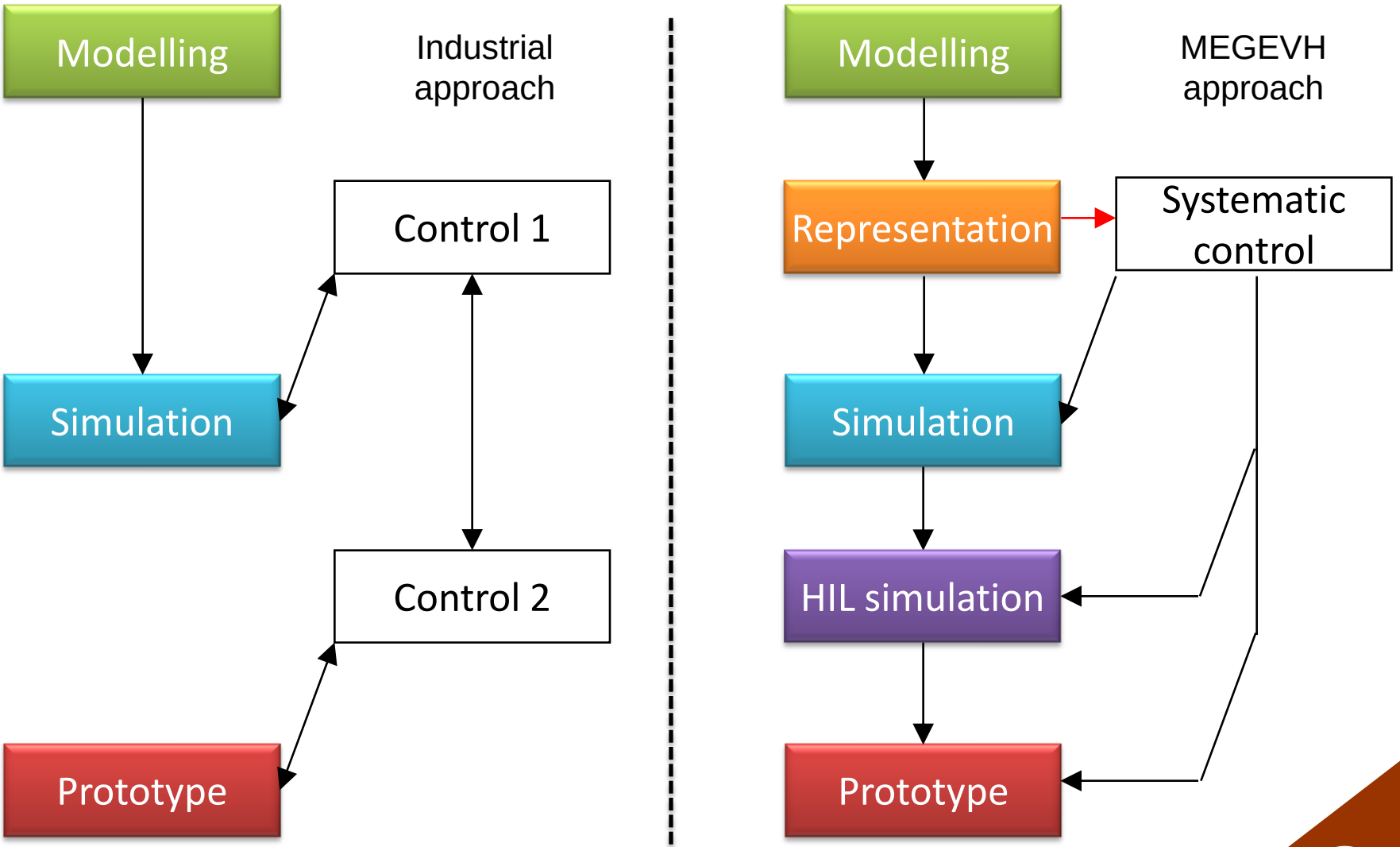
Heuristic control based on the expertise that needs a significant development time





How to structure and systematize the control?

Approach of the control development



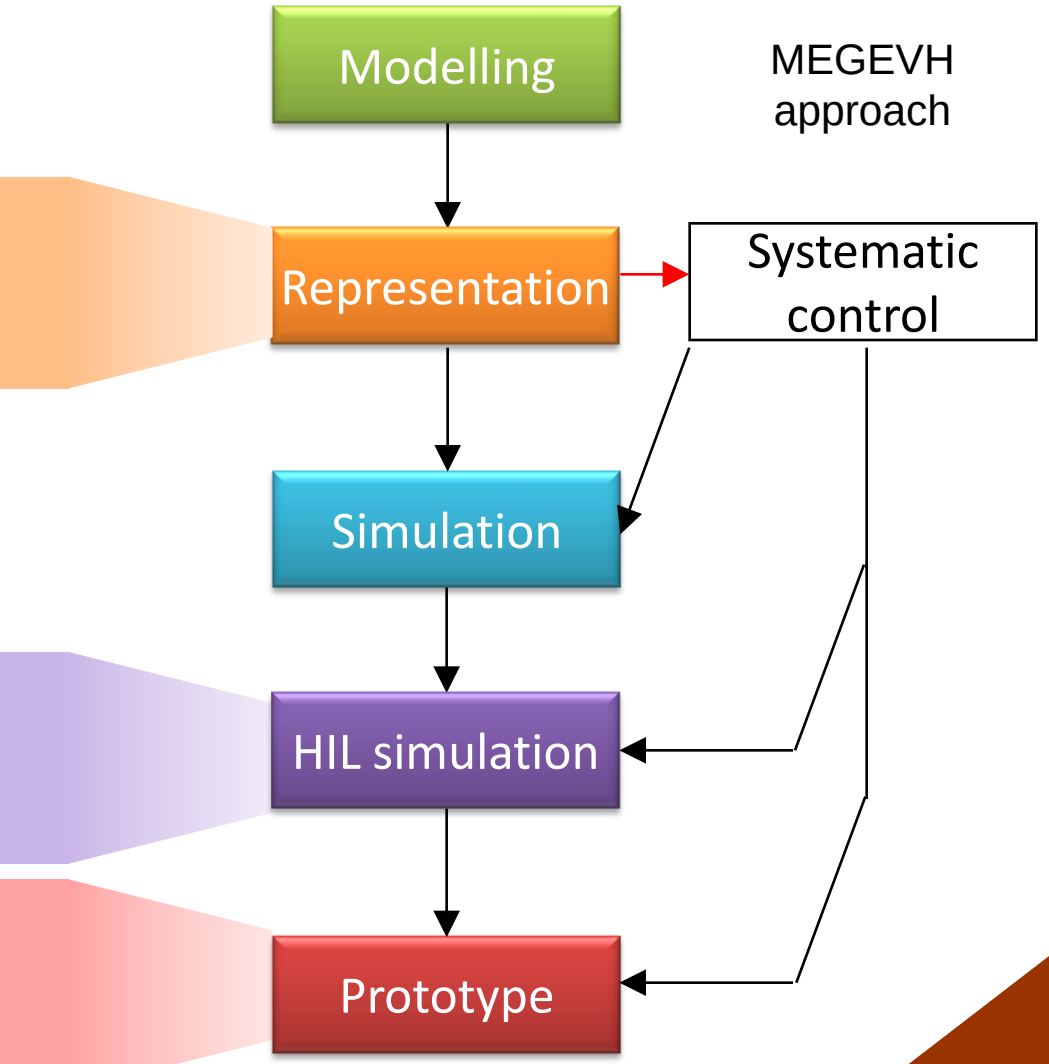
Objective: to structure the control steps of a complex vehicle (structuration level, progressive validations, implementation)

Outline

1. EMR and control of the HYbrid4

2. Power HIL simulation of the HYbrid4

3. Experimentation on a HYbrid4 prototype



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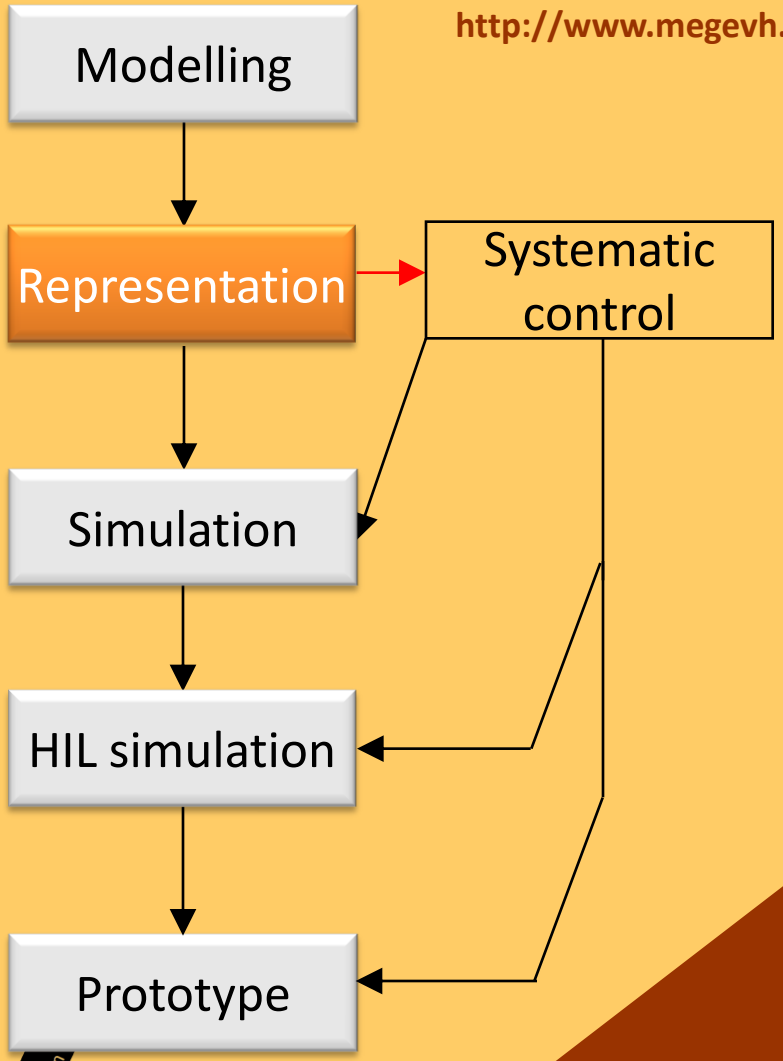
1. EMR and control of the HYbrid4



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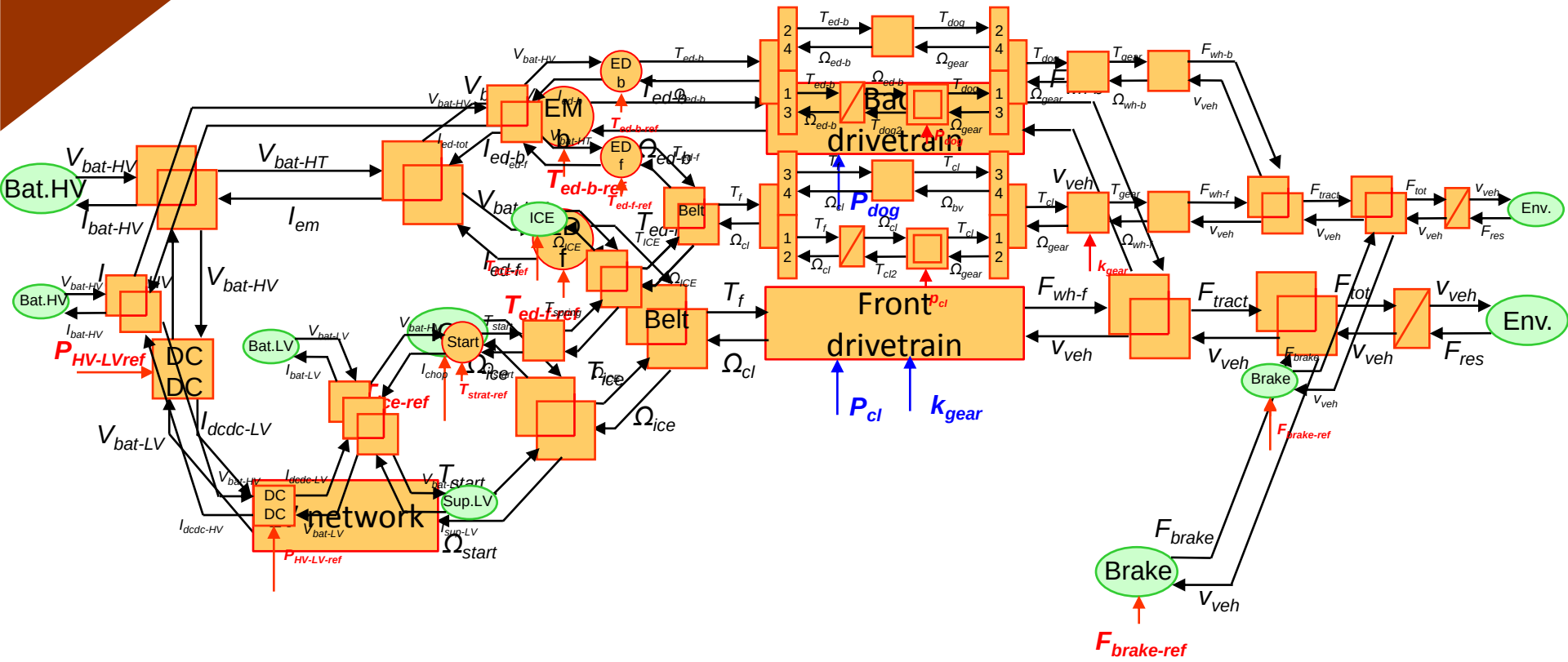
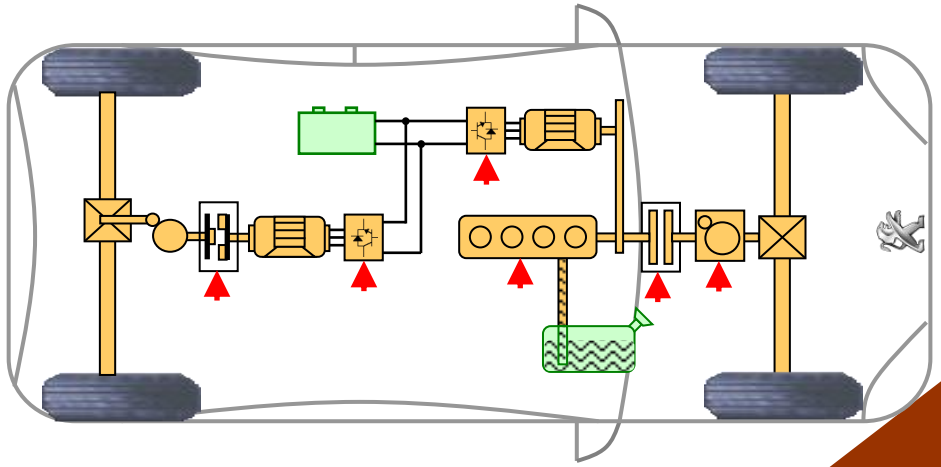
EMR of the HYbrid4

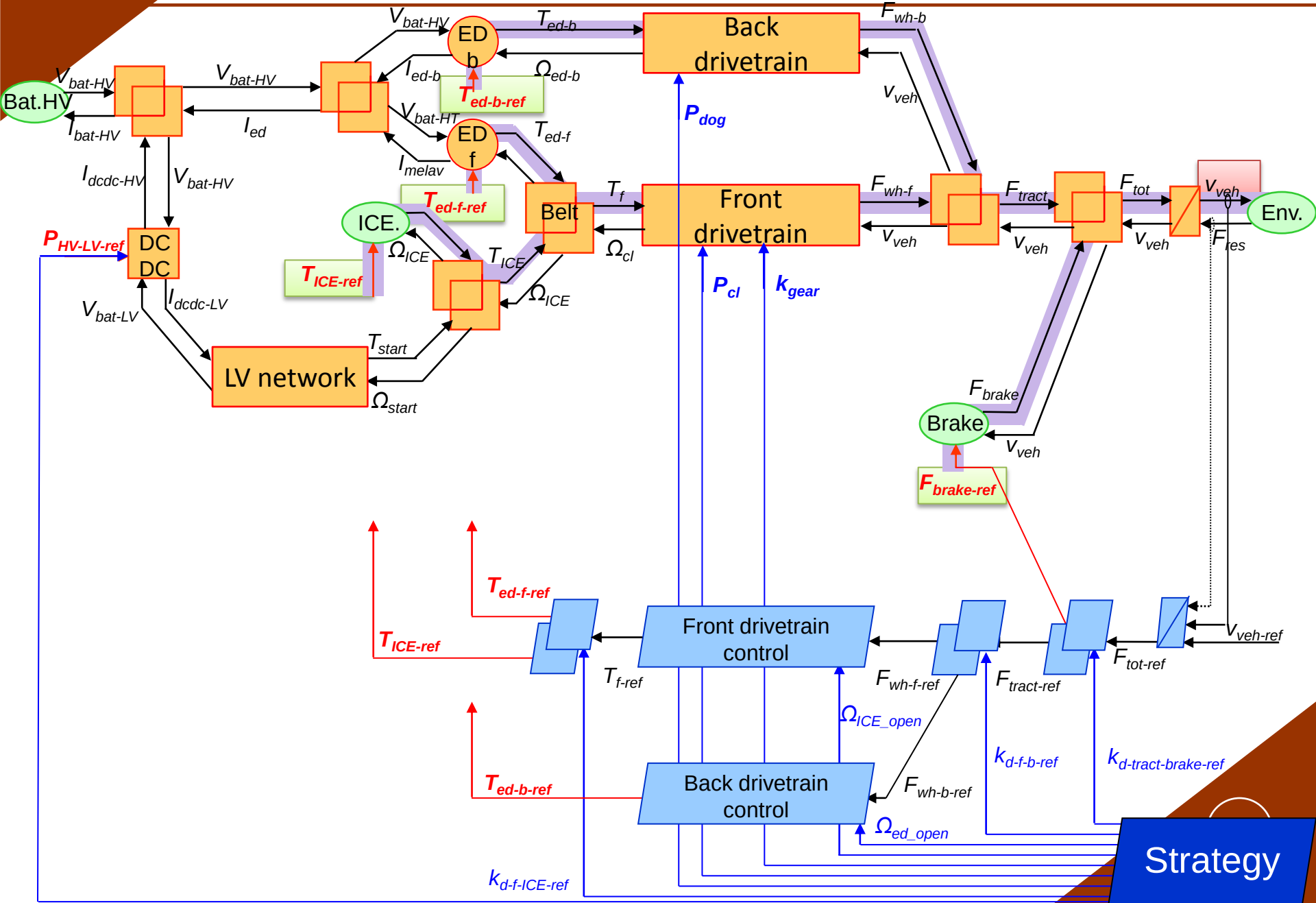


EMR points out the:

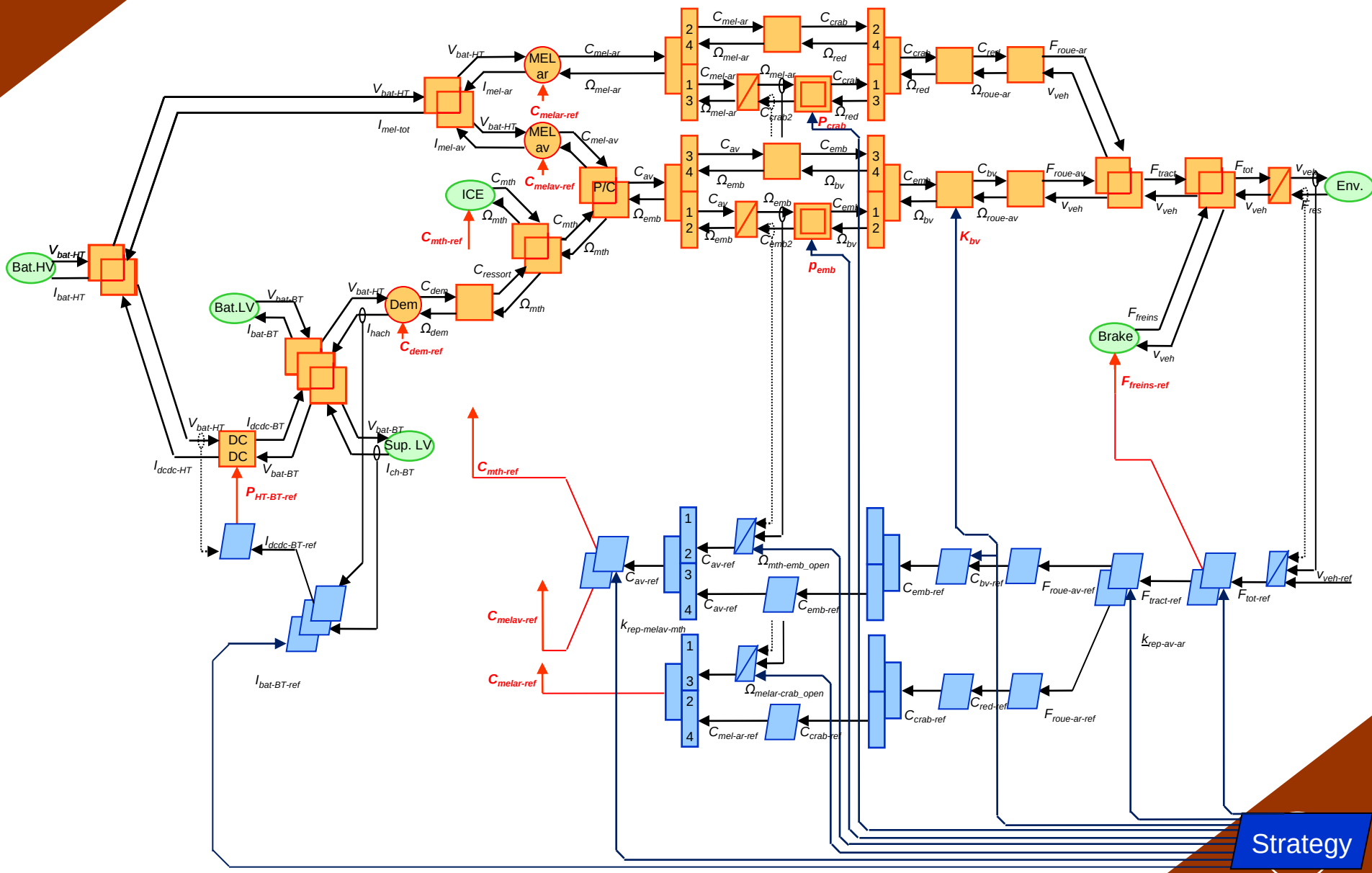
- energetic flows
- key variables for the control



Inversion-based control



Inversion-based control



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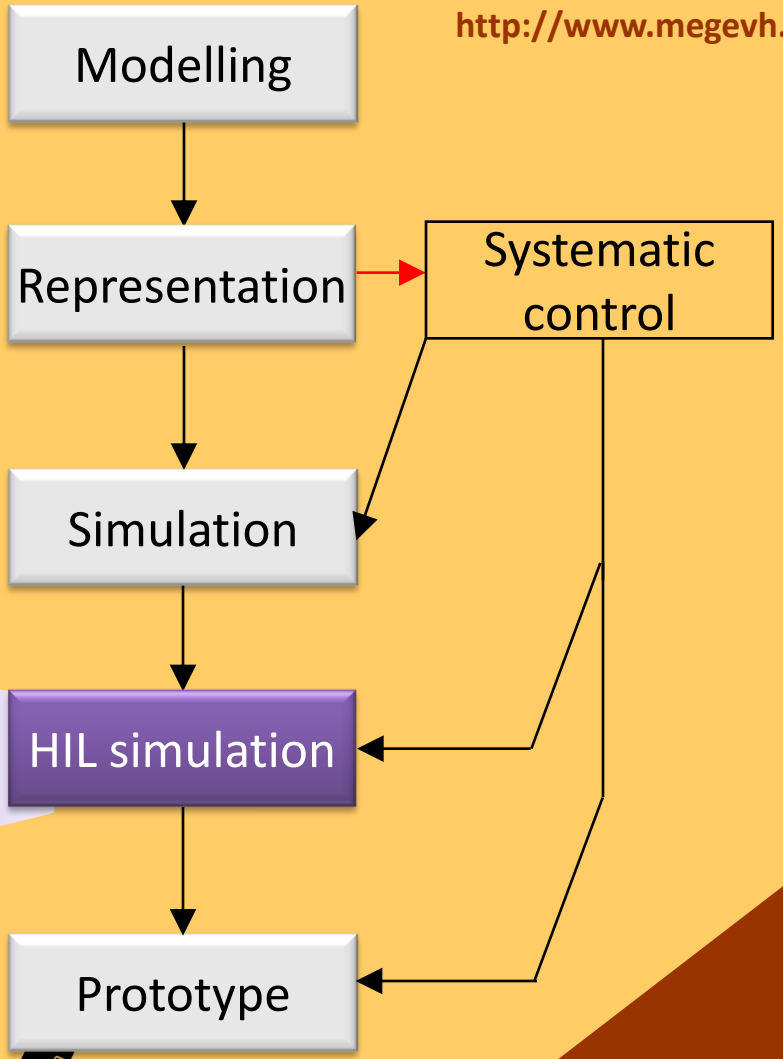

2. Power HIL Simulation of the HYbrid4

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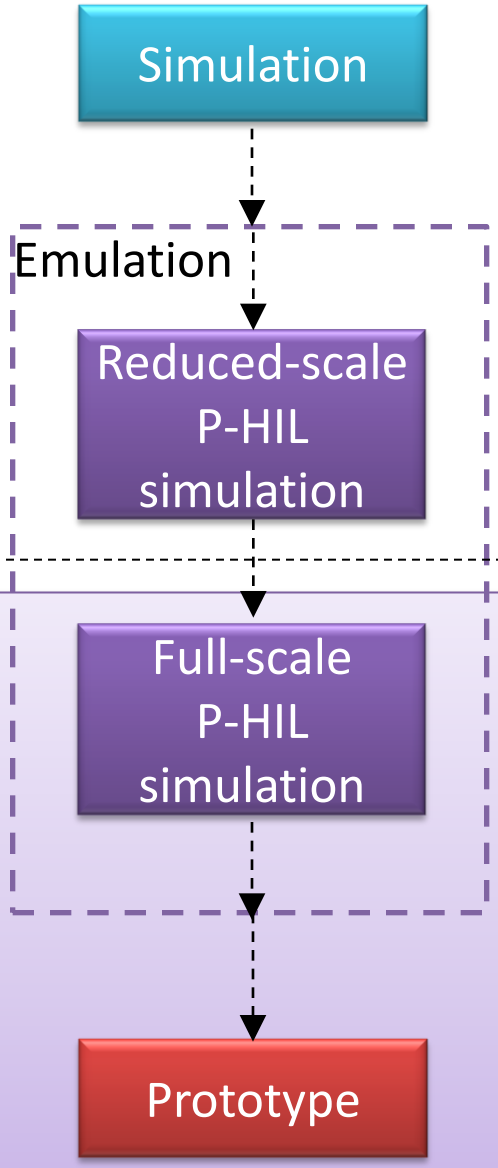
Two kinds of power HIL simulation

Available platform:
1.5 kW (DCM & IM)

Specific platform:
10 kW – 20 kW (PMSM)



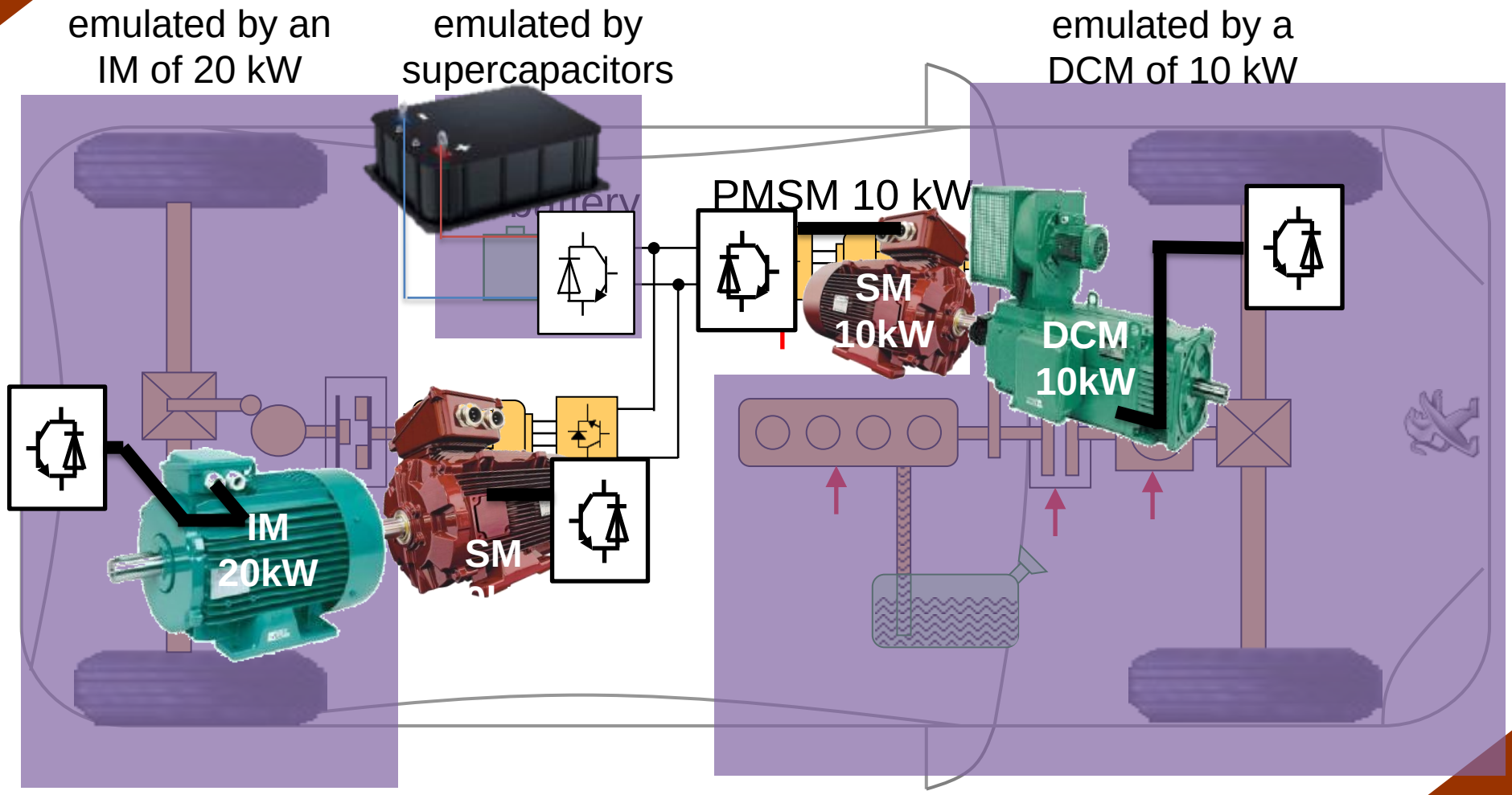
Objectives:

- validation of the portability in real-time of the defined systematic control
- preparation for the full-scale P-HIL simulation

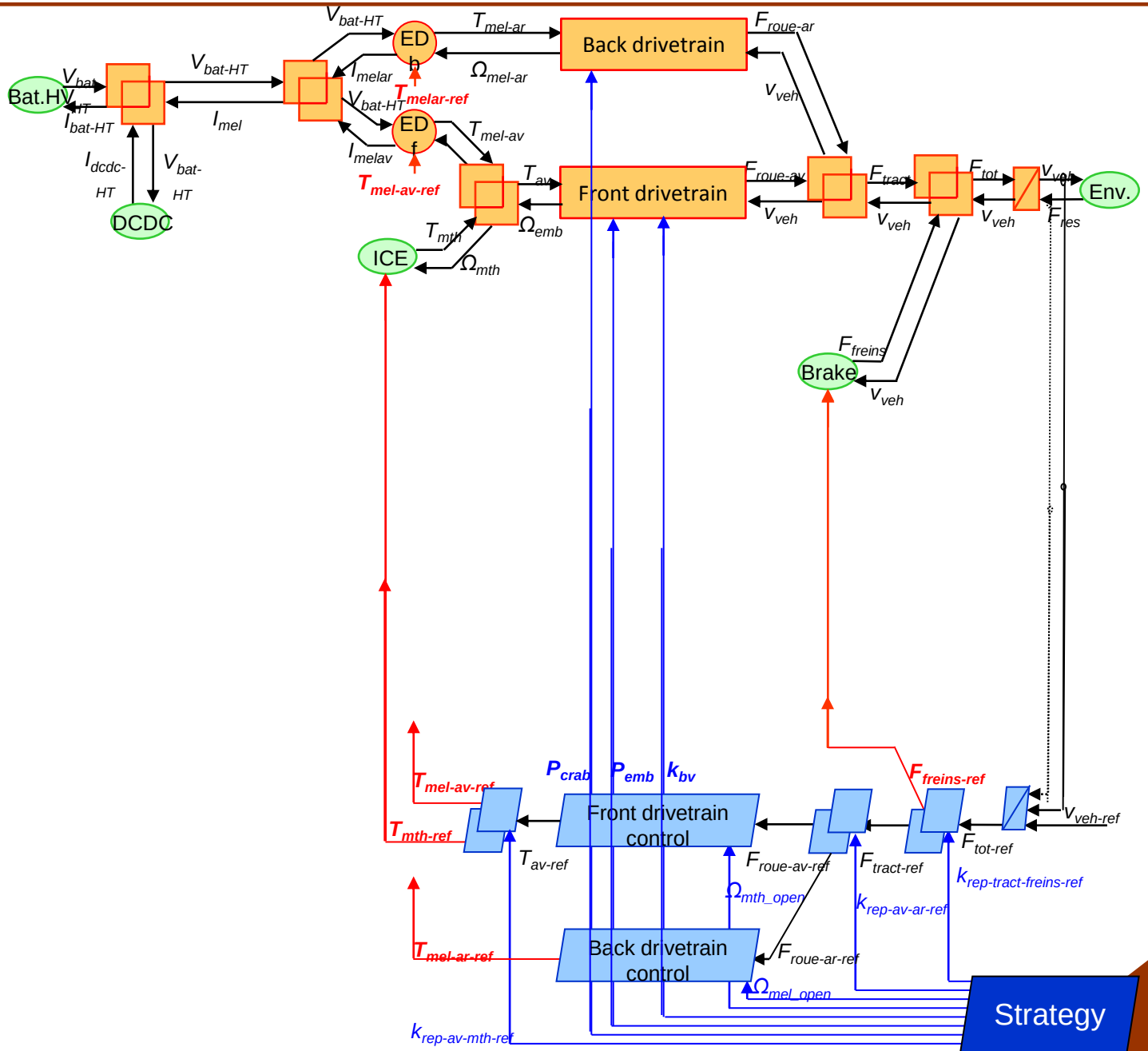
Objectives:

- validation of the real subsystems (electric drives) on a platform dedicated as close as possible to the vehicle environment
- Study of the limitations and fault-tolerant modes

Power HIL simulation of the HYbrid4 – platform



Power HIL simulation of the HYbrid4 – EMR



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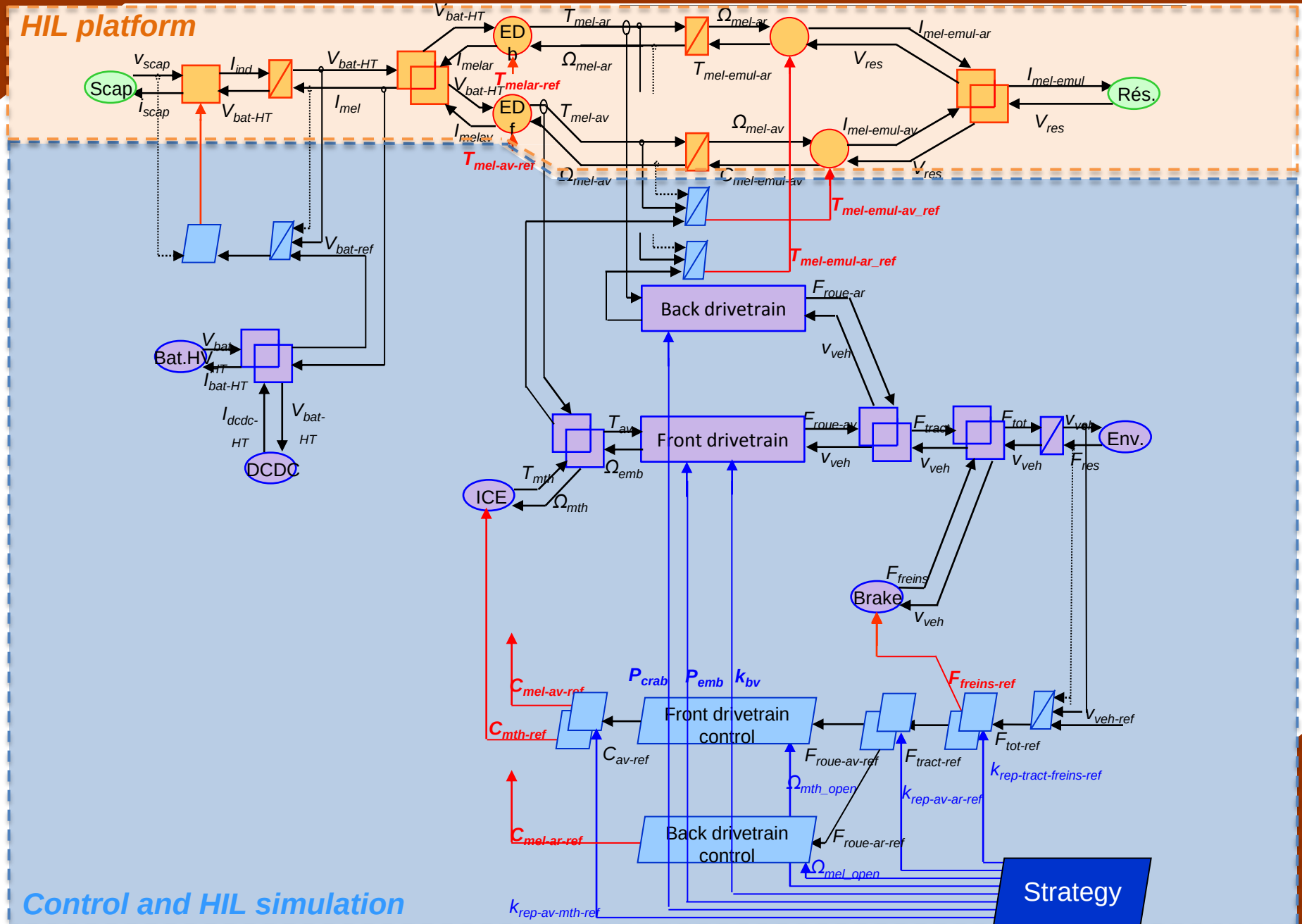
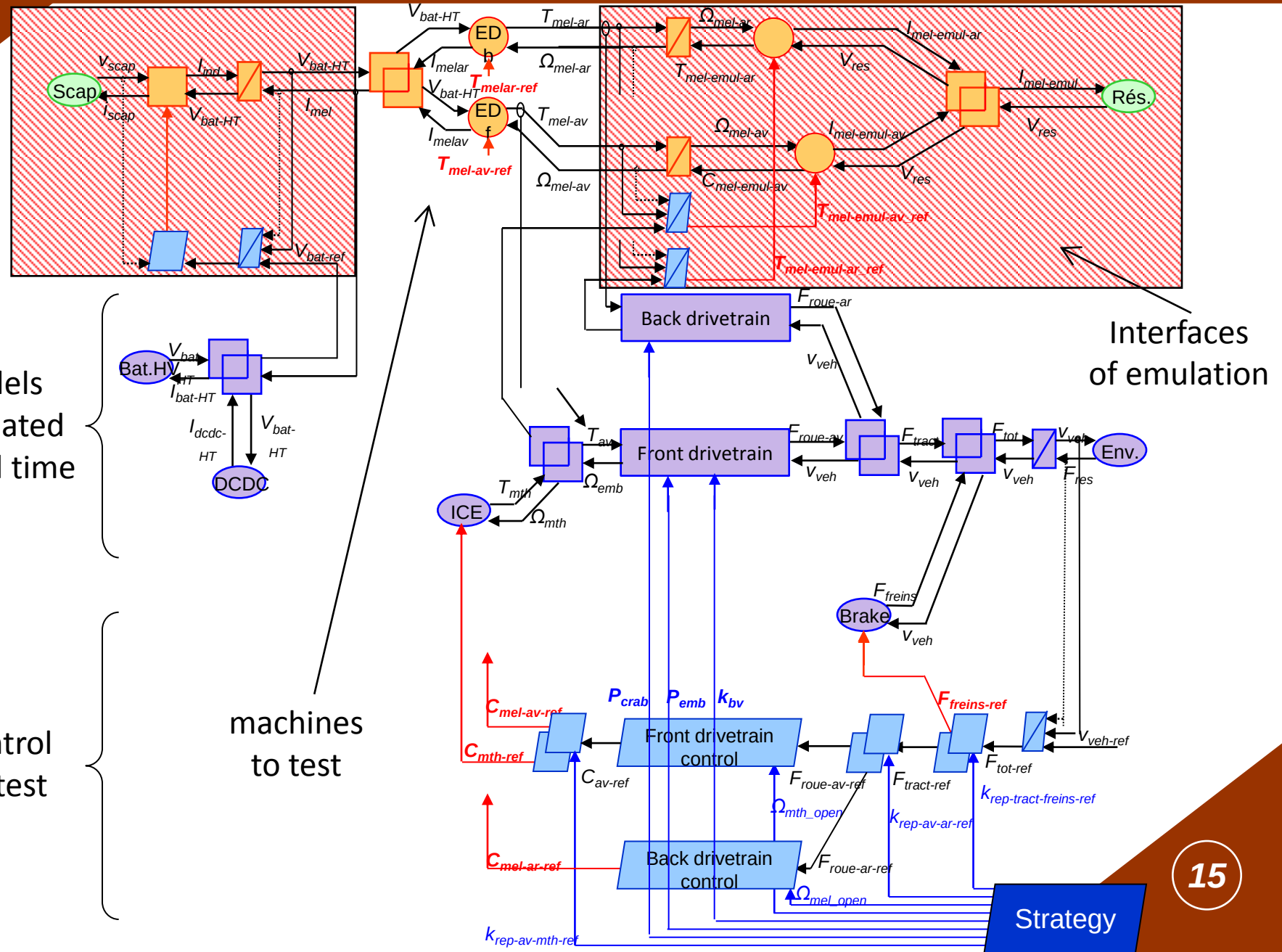
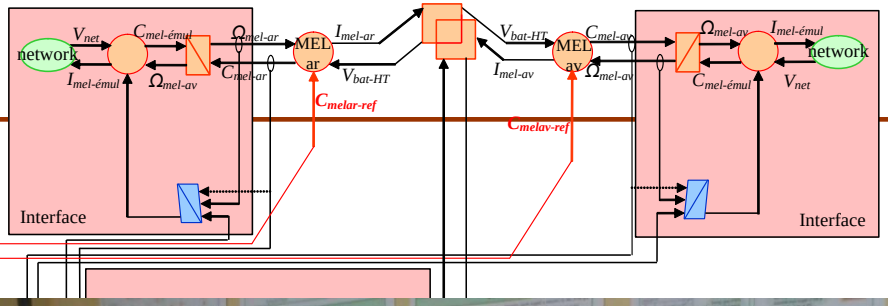
Power HIL simulation of the HYbrid4 – EMR



Power HIL simulation of the HYbrid4 – EMR

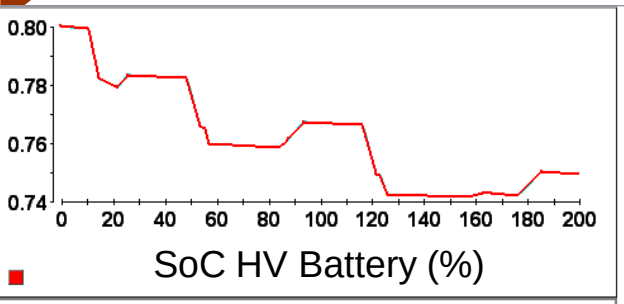



network
V_{net}
$C_{mel-émul}$
$I_{mel-émul}$
Ω_{mel-av}
Ω_{mel-ar}
C_{mel-ar}
MEL ar
I_{mel-ar}
V_{bat-HT}
$C_{melar-ref}$
V_{bat-HT}
I_{mel-av}
MEL av
C_{mel-av}
Ω_{mel-av}
$C_{melav-ref}$
Ω_{mel-av}
$I_{mel-émul}$
network
$C_{mel-émul}$
V_{net}
Interface
Interface

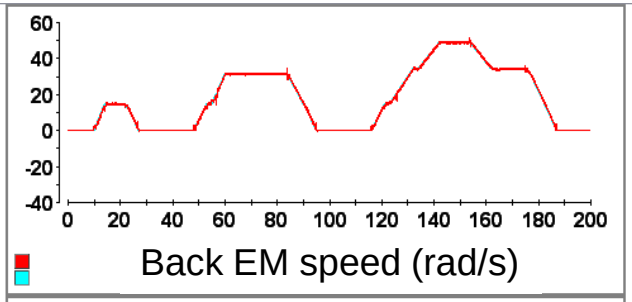

Electronique de Puissance + Supervision
Chaine de Traction Arrière Emulée
Machine électrique Arrière
Machine électrique Avant
Chaine de Traction Emulée + Mch Em

Stratégie

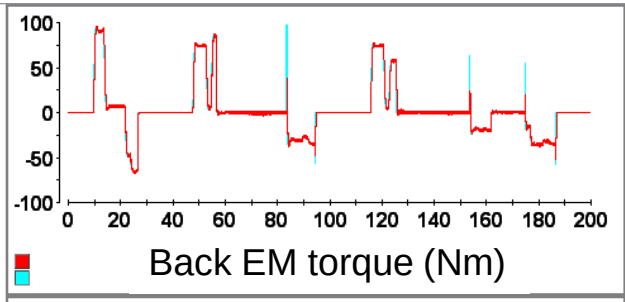
Experimental results



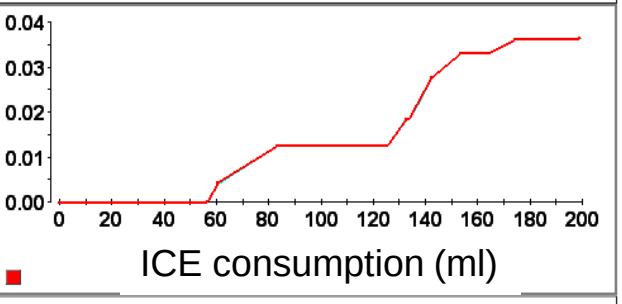
SoC HV Battery (%)



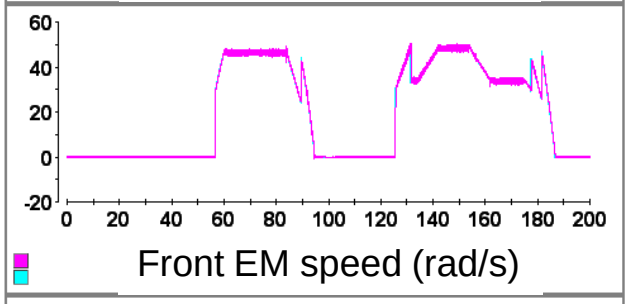
Back EM speed (rad/s)



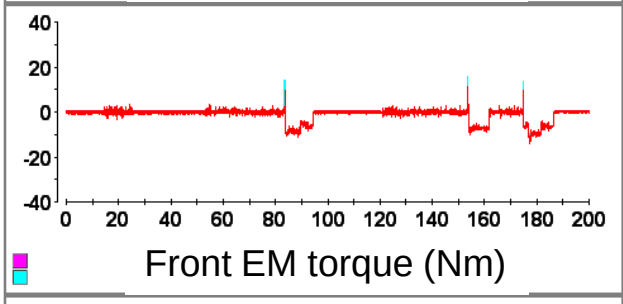
Back EM torque (Nm)



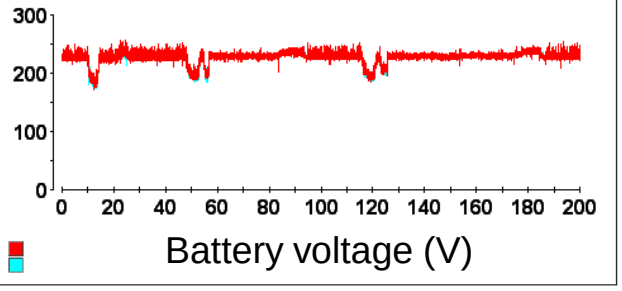
ICE consumption (ml)



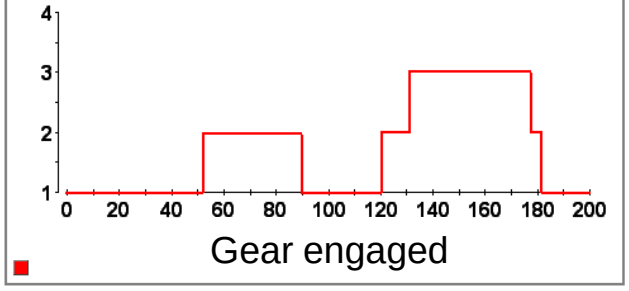
Front EM speed (rad/s)



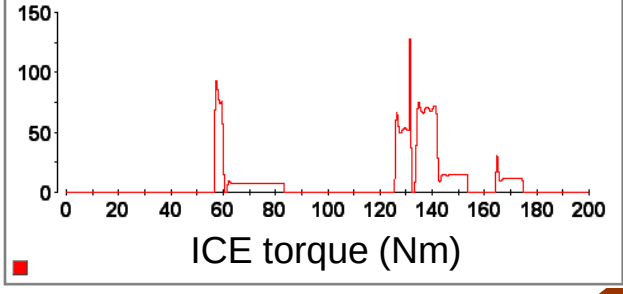
Front EM torque (Nm)



Battery voltage (V)



Gear engaged



ICE torque (Nm)

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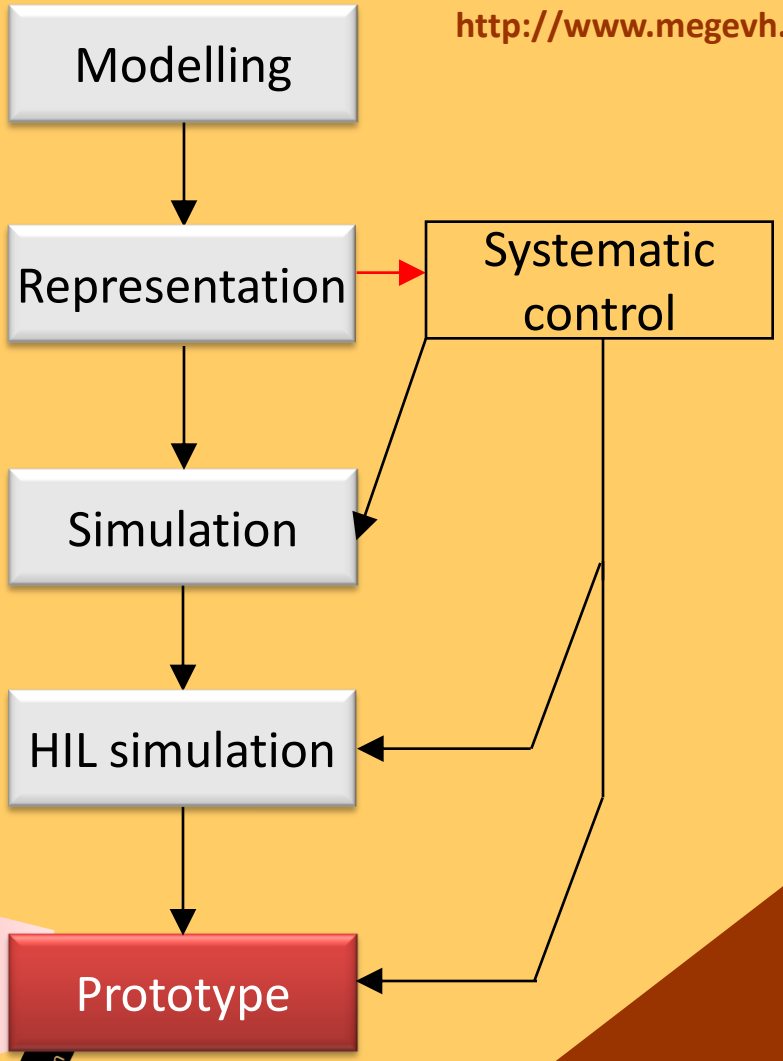

3. Experimentation on a HYbrid4 prototype

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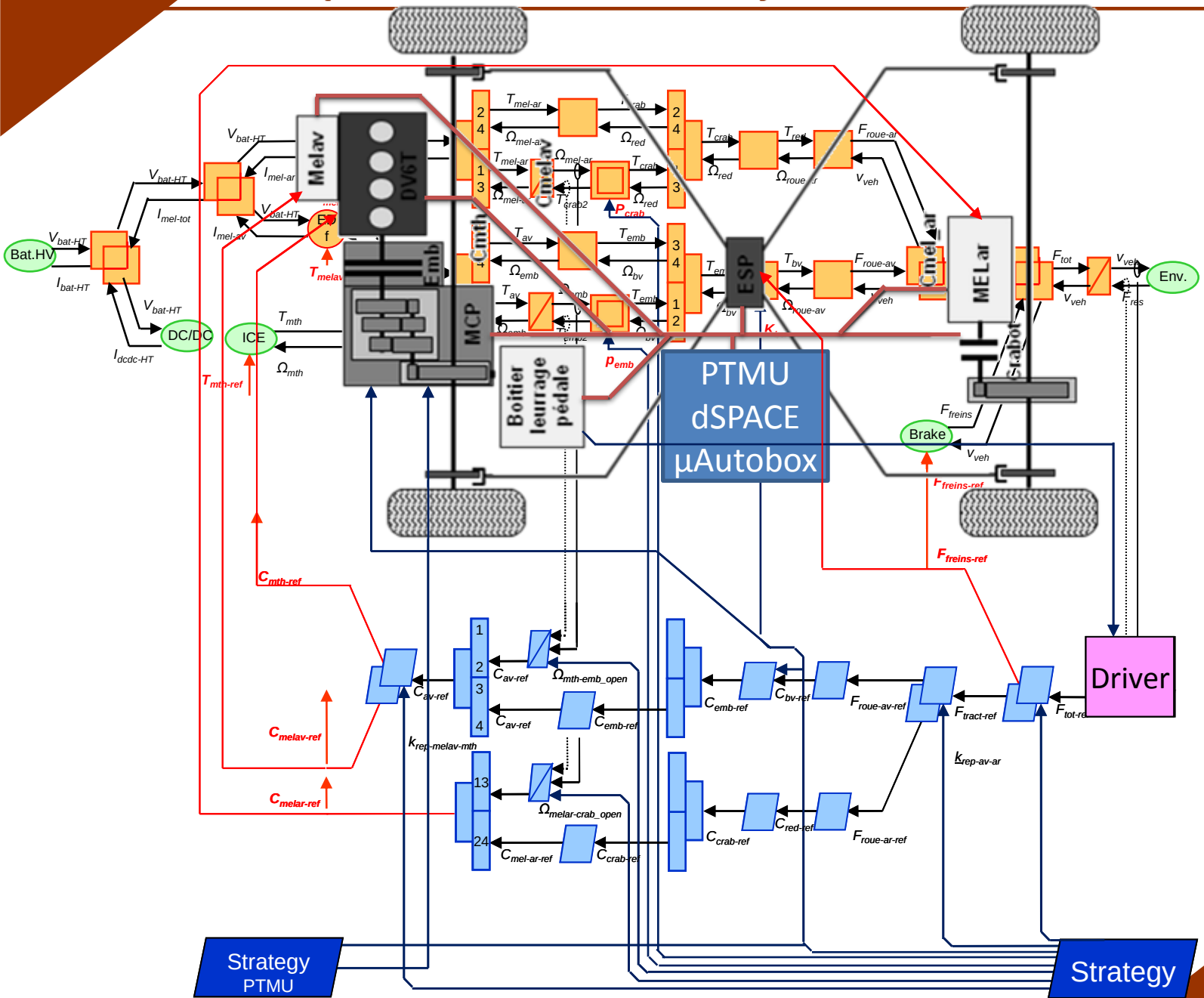
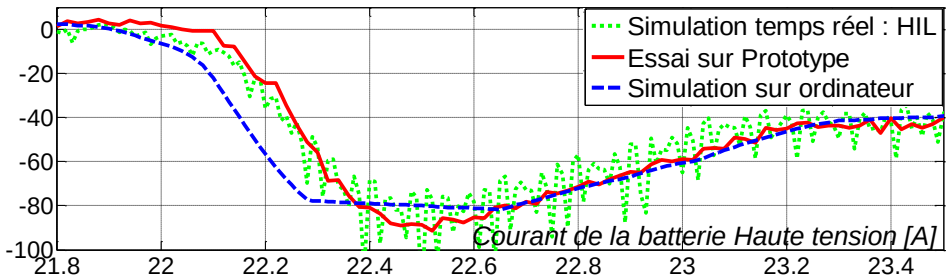
Implementation of the systematic control to the vehicle



Comparisons of the results

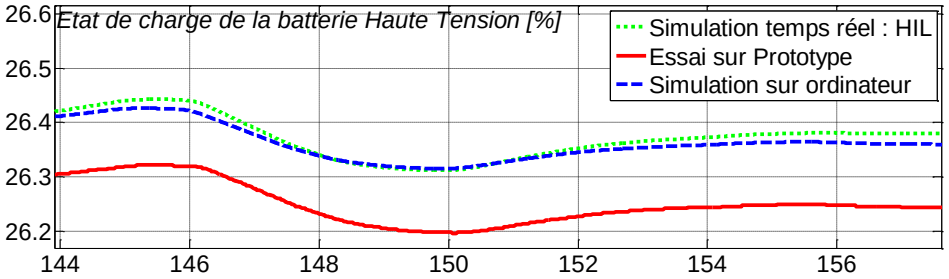
Current of the HV battery (A)



HIL dynamics closer than simulation that uses a static modelling
-> Advantage of the HIL platform: open platform

Power HIL simulation
Prototype
Simulation

SoC of the HV battery (%)



Modelling complexity of the “critical” components (eg. HV battery)
-> Use of the real component into a power HIL simulation

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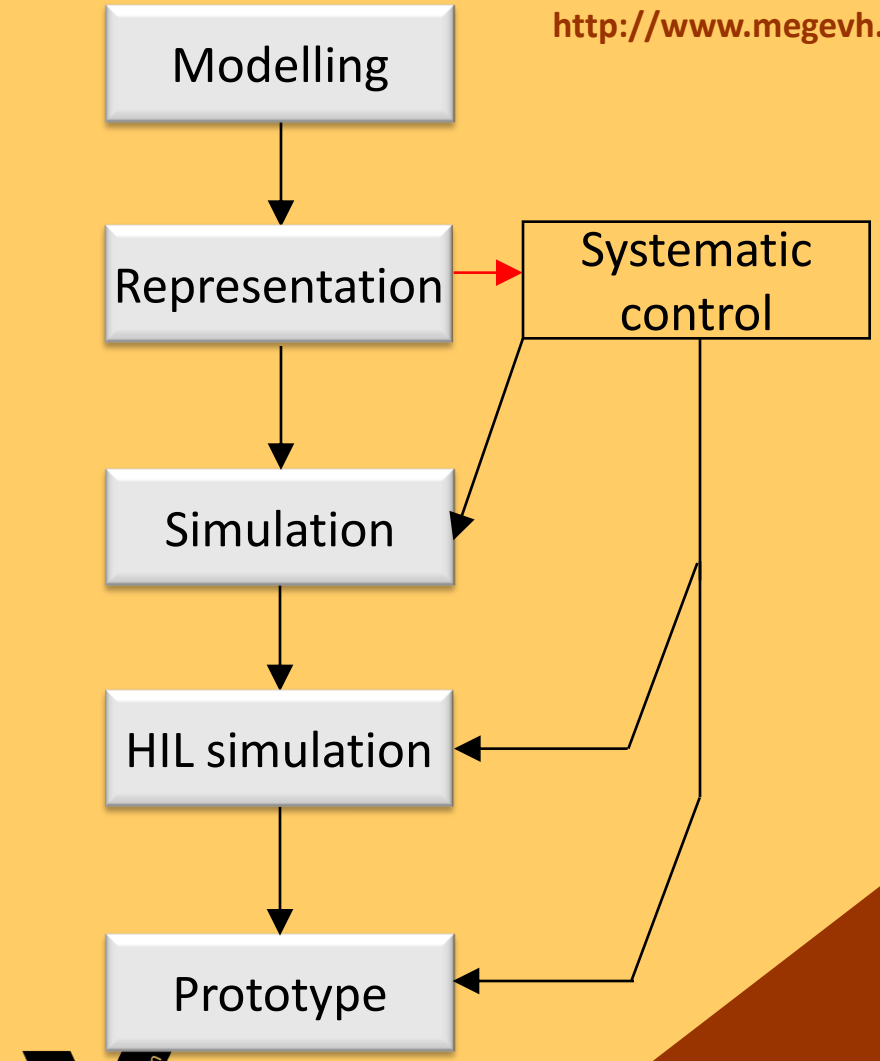
Conclusion



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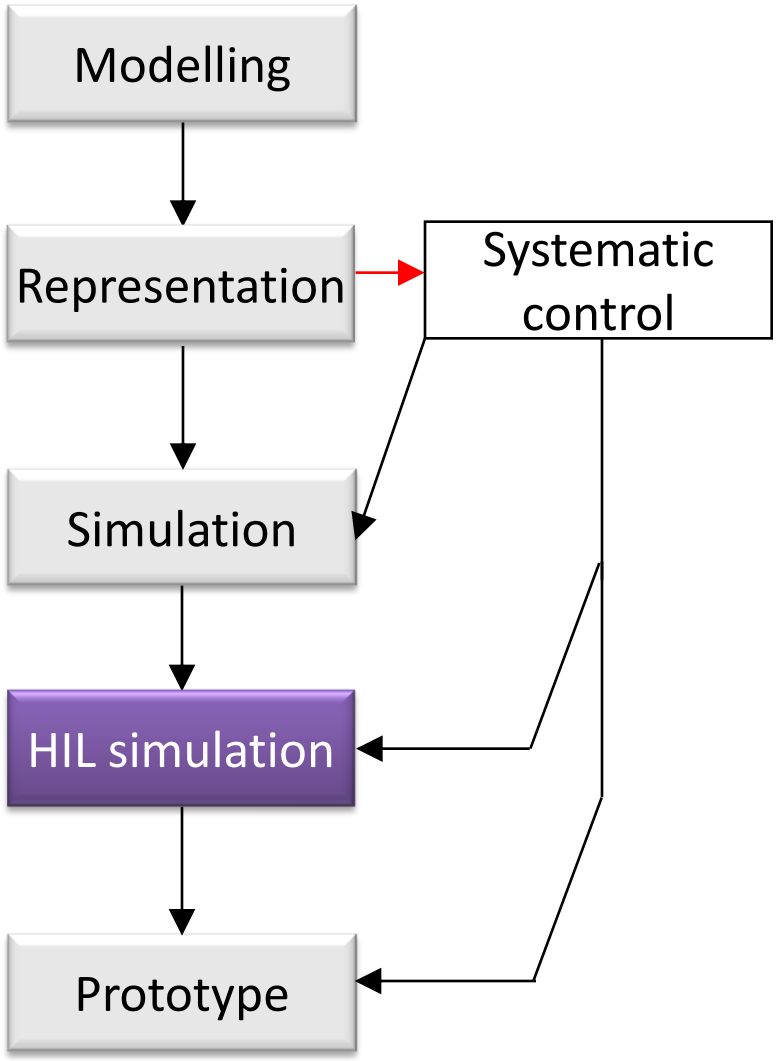
Conclusion

HIL simulation

• Validation of the control and the subsystems on a dedicated platform (reduced-scale or/and full-scale)

The EMR formalism as structuration and articulation tool of the different parts



Interest:

- progressive validation method
- same inversion-based control used from the simulation to the prototype
- direct implementation of the control (no back-and-forth)

References

[Letrouvé 09a] T. Letrouvé, P. Delarue, A. Bouscayrol, "Modelling and control of a double parallel hybrid electric vehicle using Energetic Macroscopic Representation", **Electromotion'09**, Lille, France, July 2009.

[Letrouvé 09b] T. Letrouvé, A. Bouscayrol, W. Lhomme, "Influence of the clutch model in a simulation of a parallel Hybrid Electric Vehicle", **IEEE VPPC'09**, Dearborn, USA, September 2009.

[Letrouvé 10] T. Letrouvé; A. Bouscayrol; W. Lhomme, N. Dollinger, F. Mercier Calvairac, "Different models of a traction drive for an electric vehicle simulation", **IEEE VPPC'10**, Lille, France, September 2010.

[Letrouvé 11] T. Letrouvé; A. Bouscayrol; W. Lhomme, N. Dollinger, F. Mercier Calvairac, "Inversion Based Control of a double parallel Hybrid Electric Vehicle: Validation in a structural software", **IEEE VPPC'11**, Chicago, USA, September 2011.

[Letrouvé 12] T. Letrouvé, A. Bouscayrol, W. Lhomme, N. Dollinger, F. Mercier Calvairac, "Reduced-scale Hardware-In-the-Loop Simulation of a Peugeot 3∞8 HYbrid4 vehicle", **IEEE VPPC'12**, Seoul, Korea, October 2012, 3rd Best Paper Award.

[Letrouvé 13a] T. Letrouvé, "Control structure from the simulation to the prototype of a double parallel hybrid vehicle using energetic macroscopic representation" (text in French), **PhD thesis, University of Lille 1**, March 2013, Industrial agreement with PSA Peugeot Citroën for training through research

[Letrouvé 13b] T. Letrouvé, W. Lhomme, A. Bouscayrol, N. Dollinger, "Control Validation of a Peugeot 3∞8 HYbrid4 vehicle using a reduced-scale Power Hardware-In-the-Loop Simulation", **JEET (Journal of Electrical Engineering and Technology),** September 2013

VPPC 2012 Best Paper Prize

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