Energetic Macroscopic Representation for control of energy conversion systems

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H2020 – PANDA (European Union)

GA 824256

Energy Conversion Systems

Energy Conversion Systems

manipulation of energy
with losses, delays,
and safety issues!

Interconnected subsystems
organized for a common goal
in interaction with an environment

Sustainable development:

- more electrified vehicles
- more renewable energy
- more efficient systems
- etc.

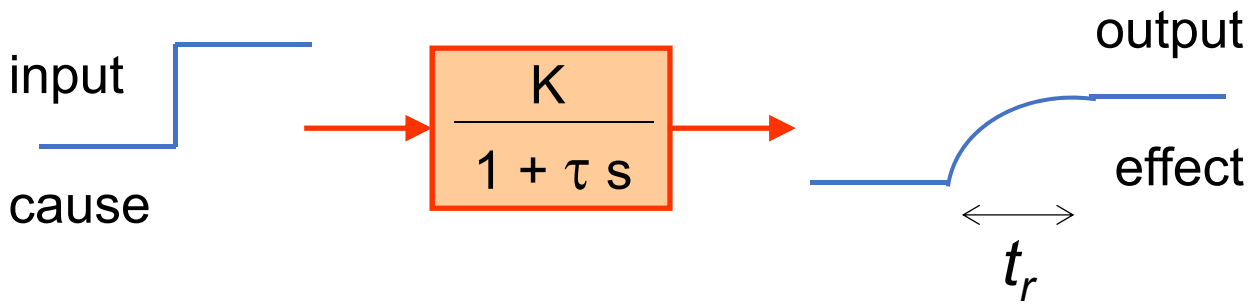
⇨ High-quality energy conversion systems

How to develop efficient control of energy conversion systems?

Causality principle

the cause leads to the effect
i.e. the output is delayed from the input
i.e. the output is an integral function of the input
i.e. the model describes an energy storage

e.g. first order system



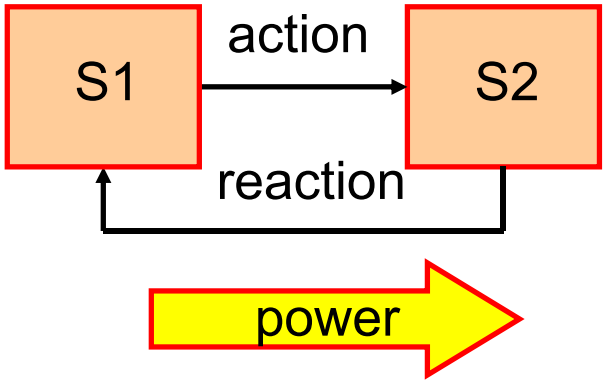
an input change leads to
an output change **with a delay**

Only integral relationships are causal
(physical behaviour, better understanding, safer management)

[Hautier 2004]

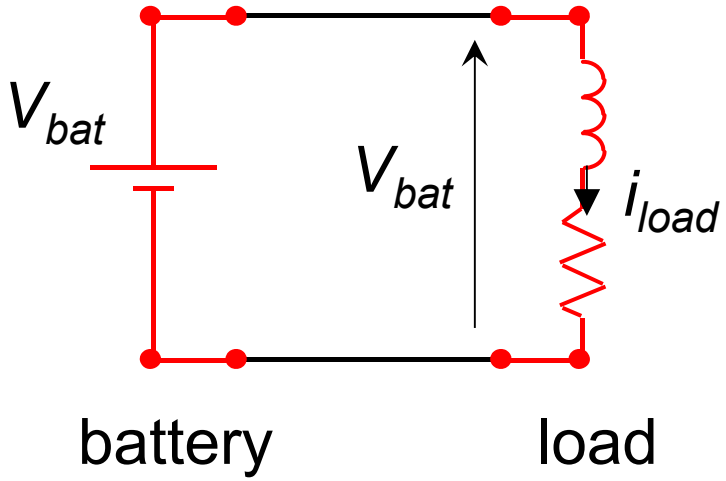
Interaction principle

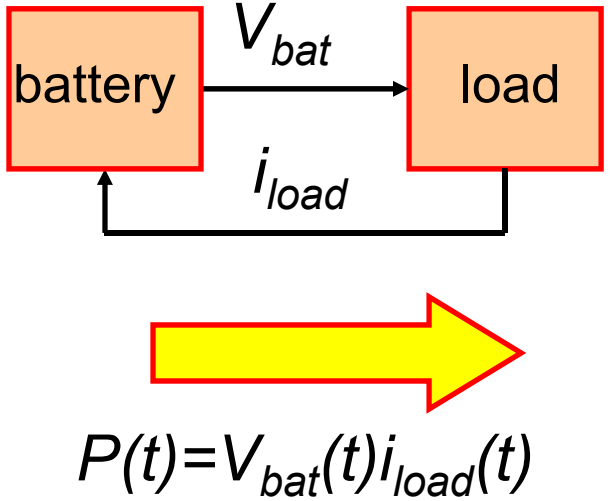
Any action induces a reaction



Power = action x reaction

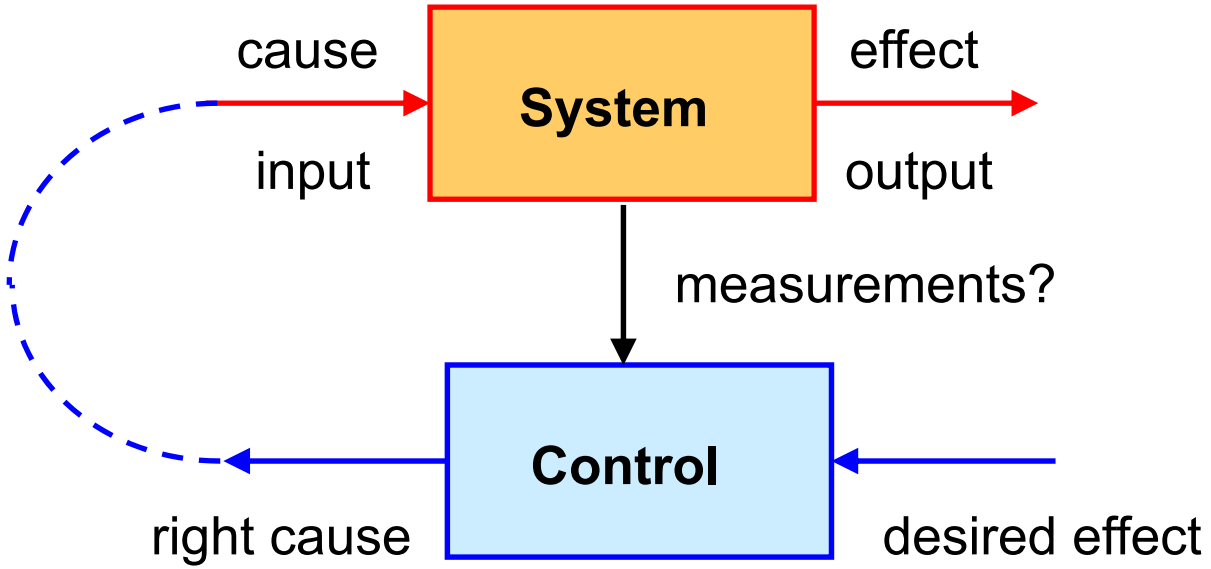
Example: battery and load





[Bouscayrol 2000]

Inversion principle



[Hautier 96]

control = inversion of the causal path

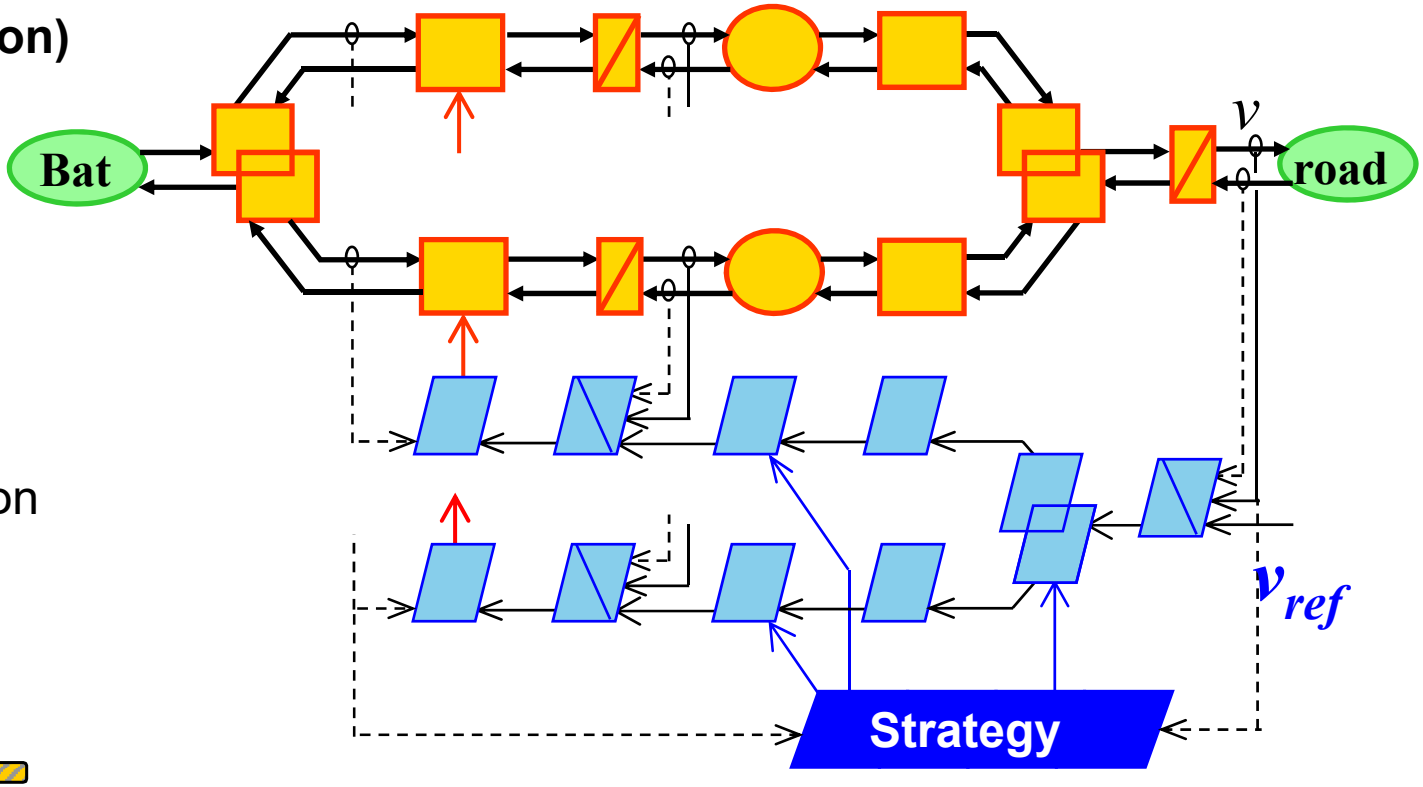
How to organize the control of innovative energy conversion systems?

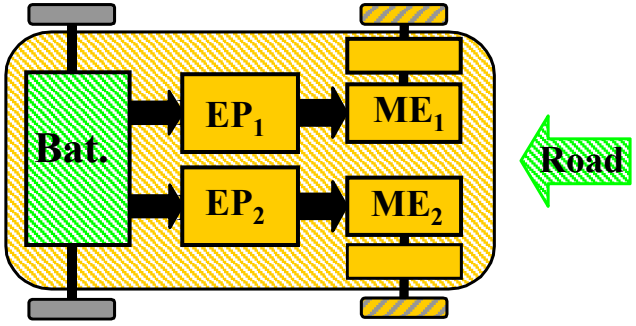
Energetic Macroscopic Representation (EMR)

What is EMR?

EMR
(graphical description)
=
organization
of models of
complex systems

Systematic deduction
of organization of
control schemes

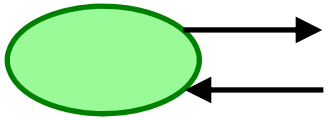




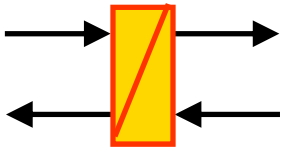
[Bouscayrol 2012]

EMR pictograms

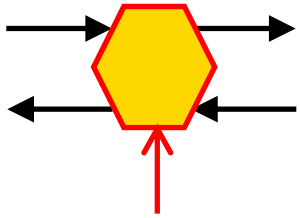
Only 4 energy functions are OK to describe energy conversion systems



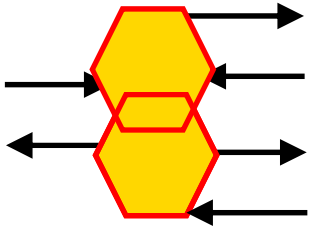
Energy source



Energy accumulation



Energy conversion (potential tuning)

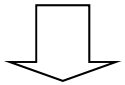


Energy distribution

all elements connected by action/ reaction (Systemics)

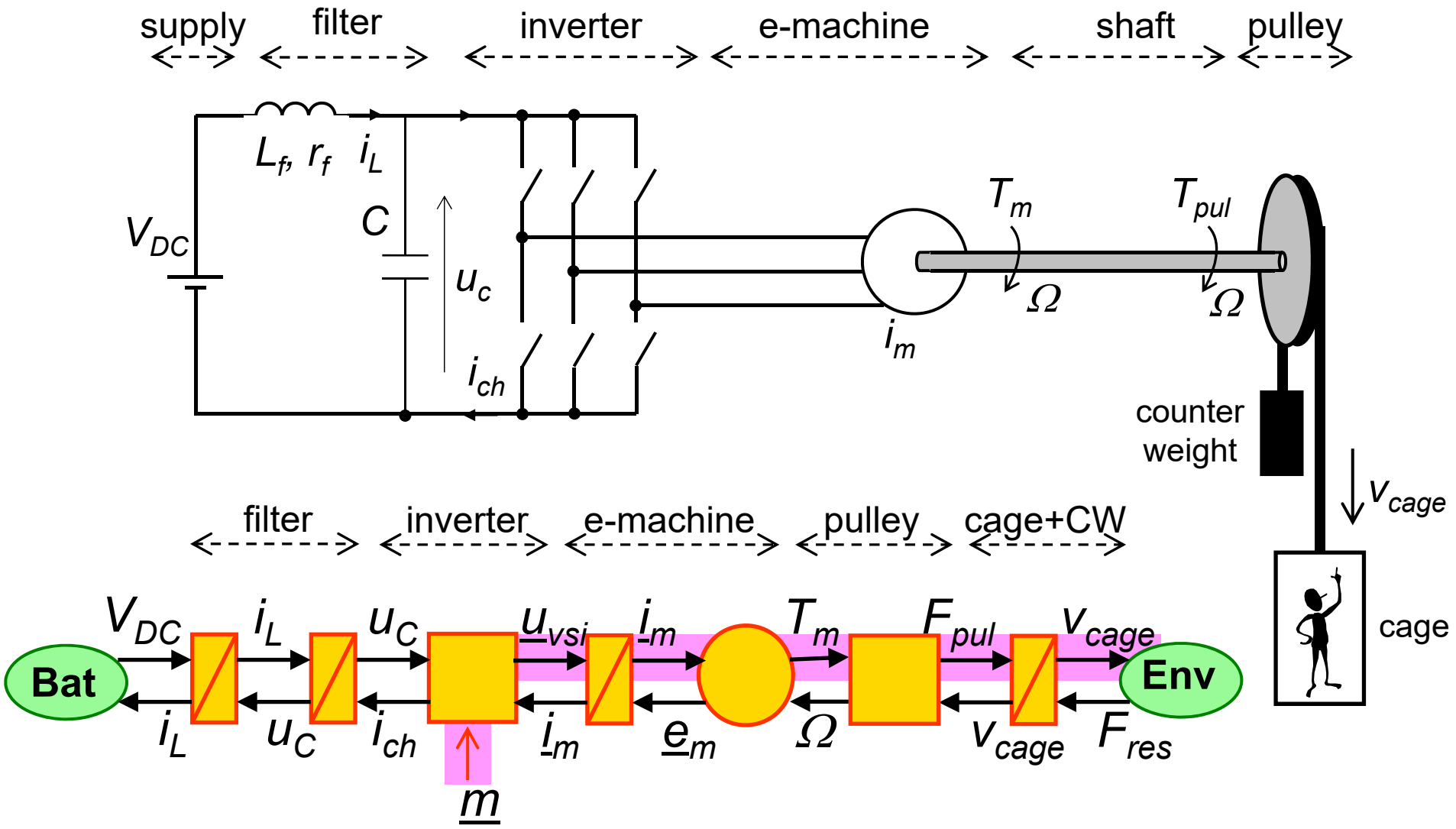
all power I/O defined by accumulation elements (causality)

only conversion elements can have tuning inputs



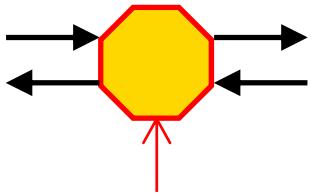
valuable for control design

EMR of a lift system

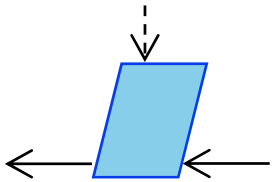


Control of EMR elements

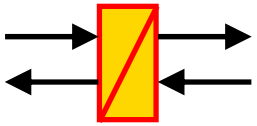
conversion element



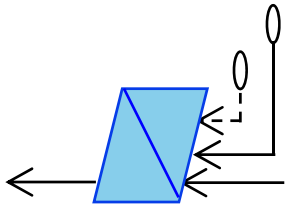
direct inversion +
disturbance rejection



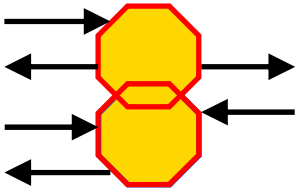
accumulation element



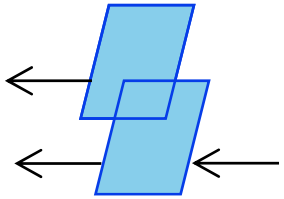
controller +
disturbance rejection



coupling element

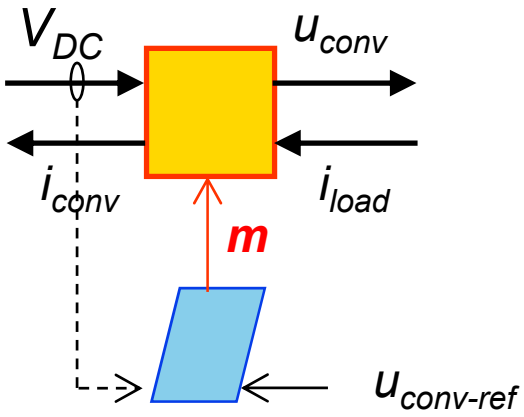


distribution criteria



Example of inversions

DC/DC converter

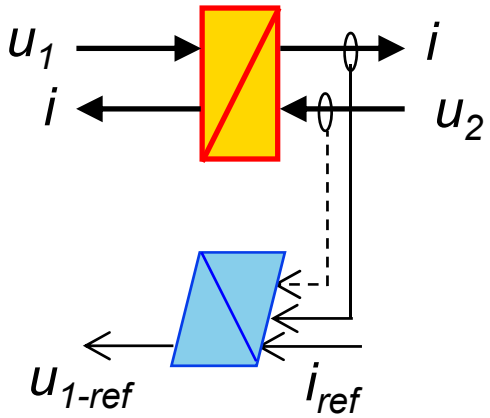


$$\begin{cases} u_{conv} = m \quad V_{DC} \\ i_{conv} = m \quad i_{load} \end{cases}$$

direct inversion

$$m = u_{conv\text{-}ref} / V_{DC\text{-}mes}$$

inductor



$$u = ri + L\, di/dt + u_2$$

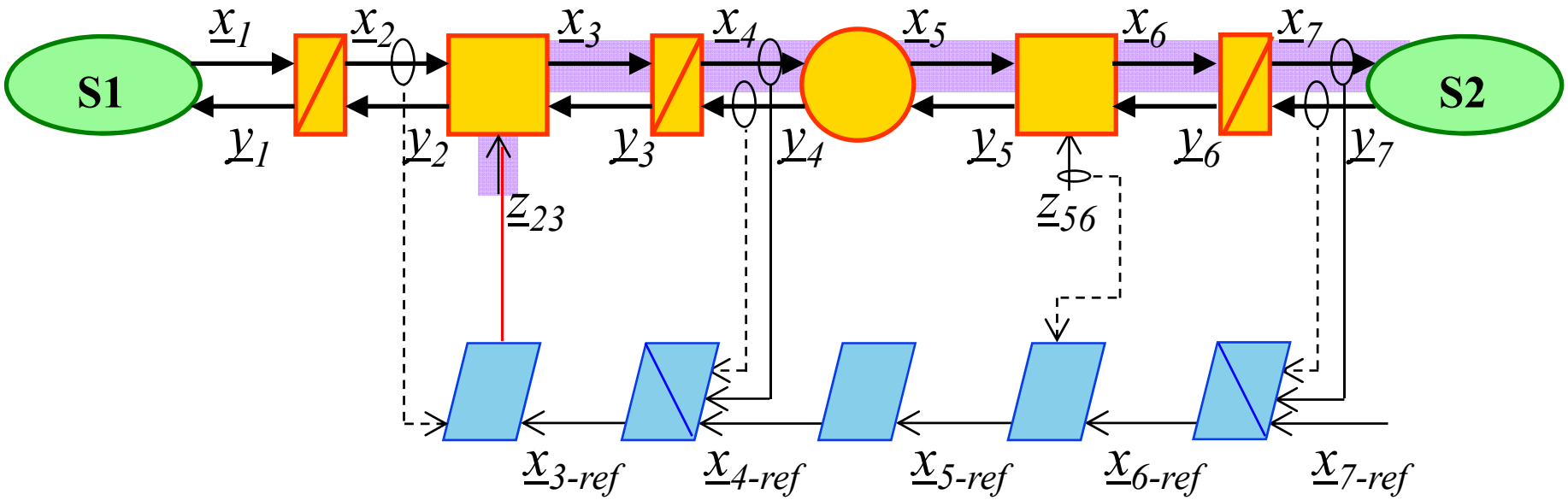
closed-loop control

$$u_{1\text{-}ref} = C(t)\,(i_{ref} - i_{mes}) + u_{2\text{-}mes}$$

Control scheme deduction (maximal)

1. EMR of the system
2. Tuning path
3. Inversion step-by-step

Strong assumption: all variables can be measured!

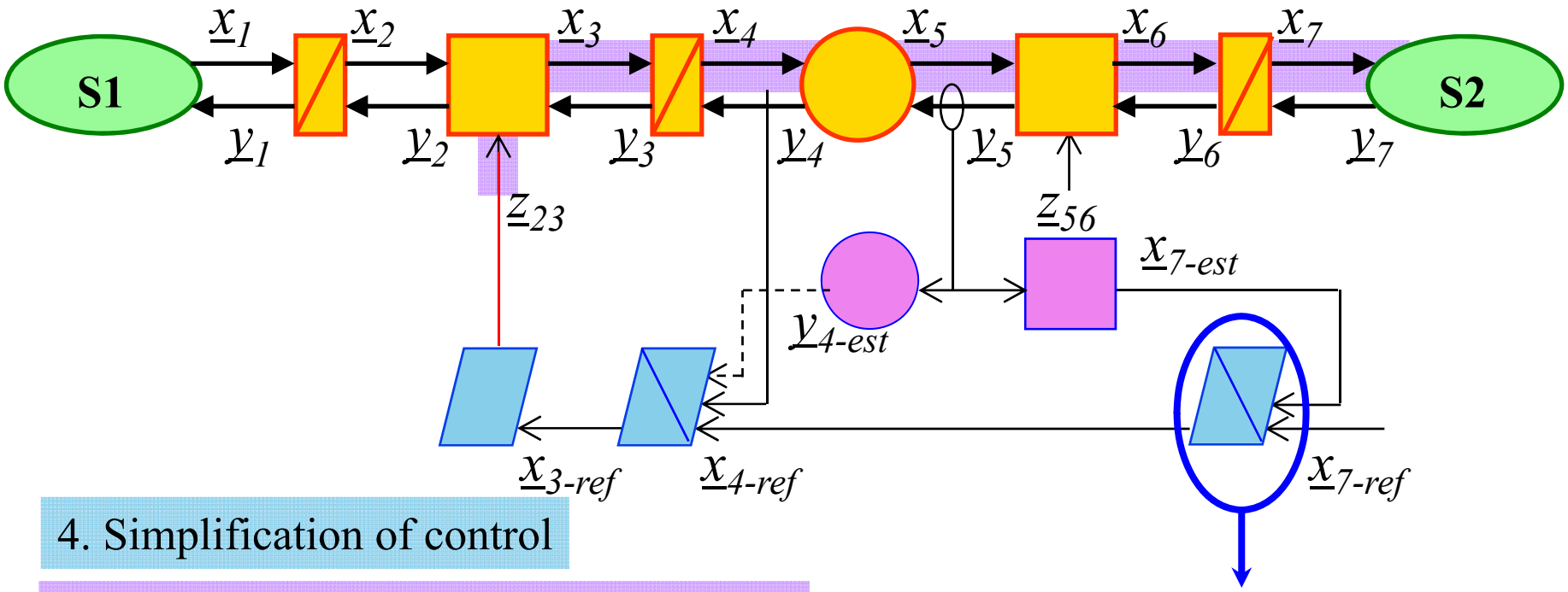


Maximal Control Structure (or scheme):
- maximum of sensors
- maximum of operations

Control scheme deduction (practical)

1. EMR of the system
2. Tuning path
3. Inversion step-by-step

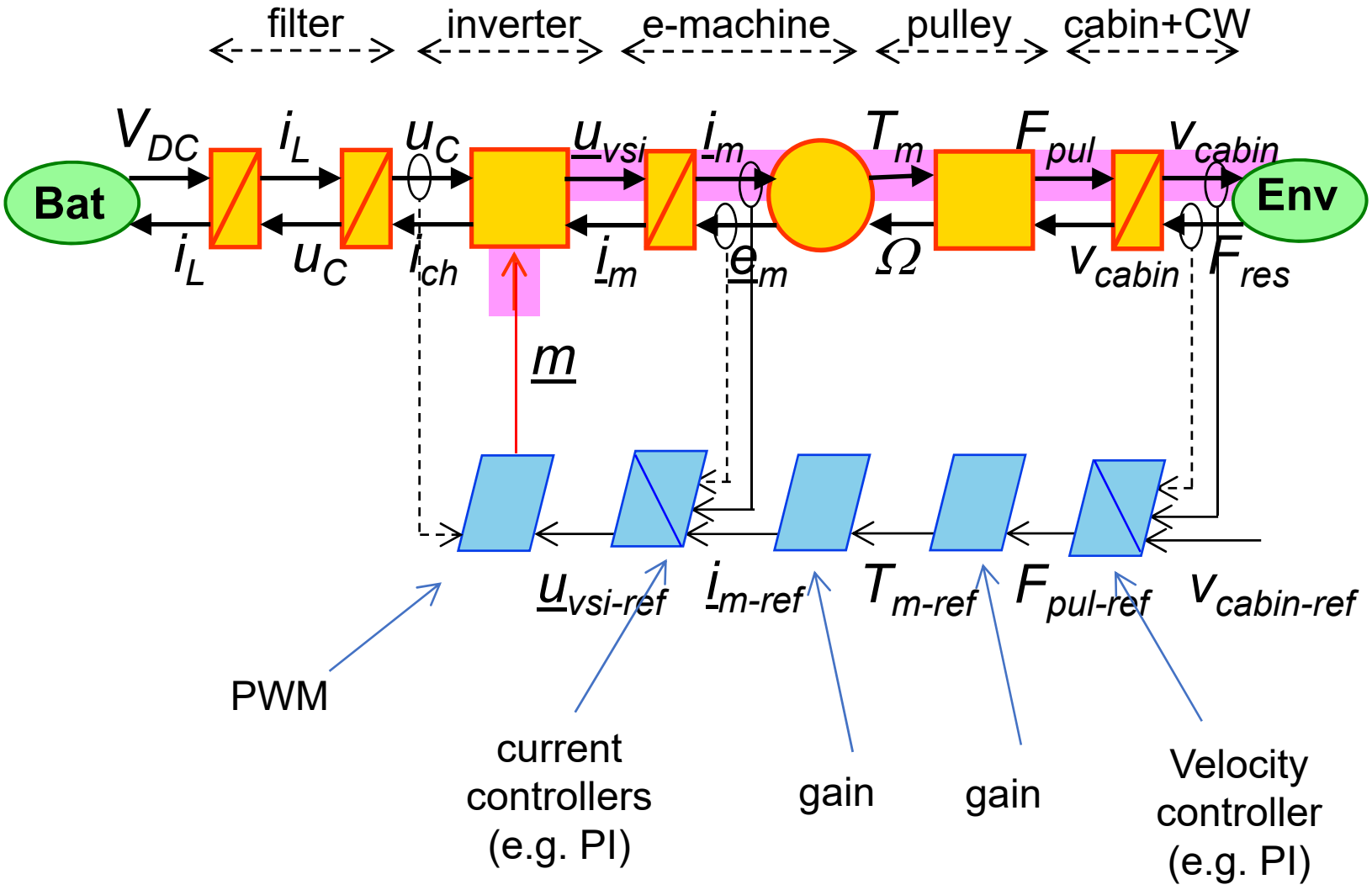
Strong assumption: all variables can be measured!



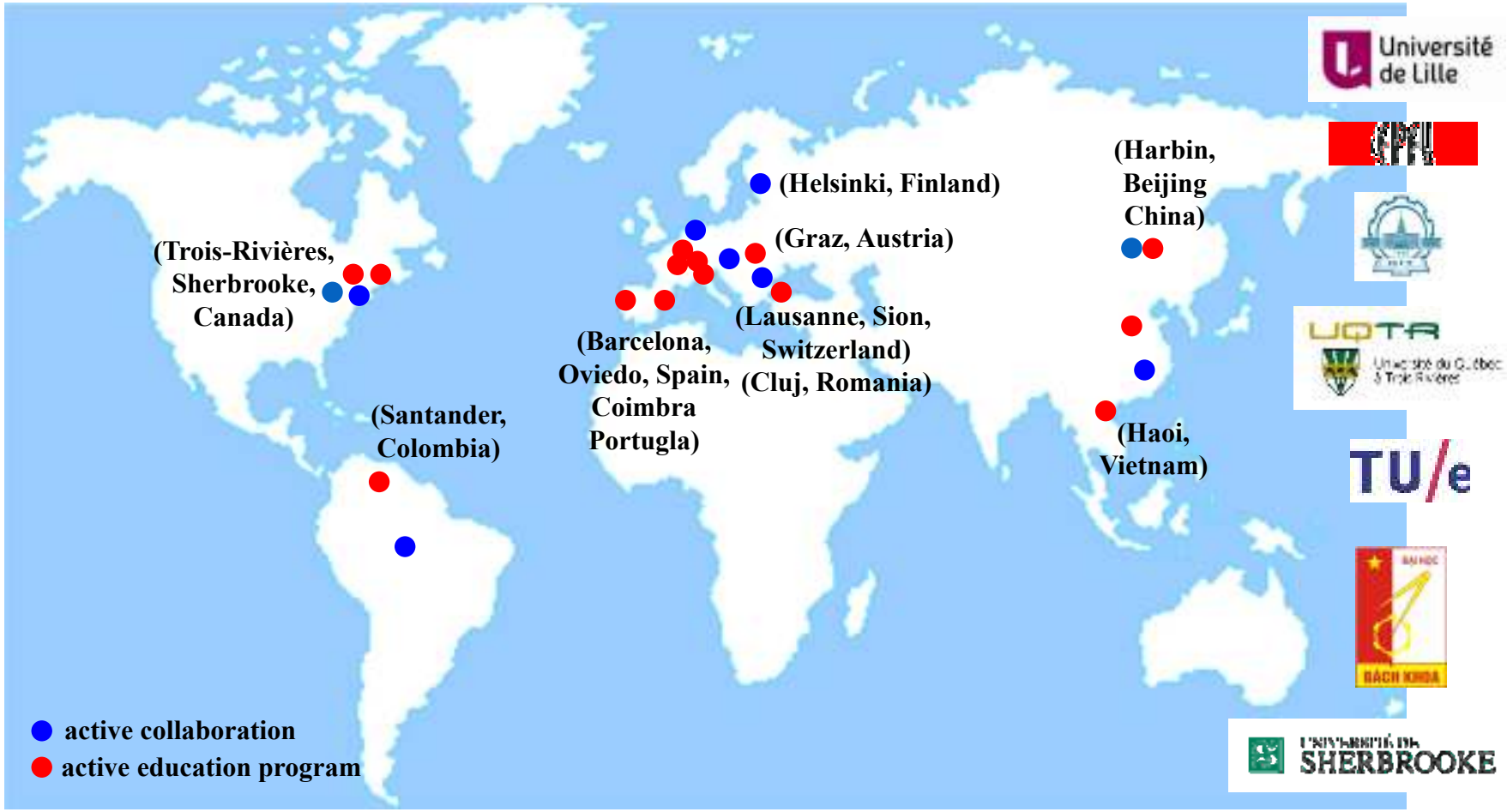
4. Simplification of control
5. Estimation of non-measured variables
6. Tuning of controllers

PI / PID / fuzzy controller?
Calculation of parameters?

Control of the lift system



EMR & dissemination



Industry

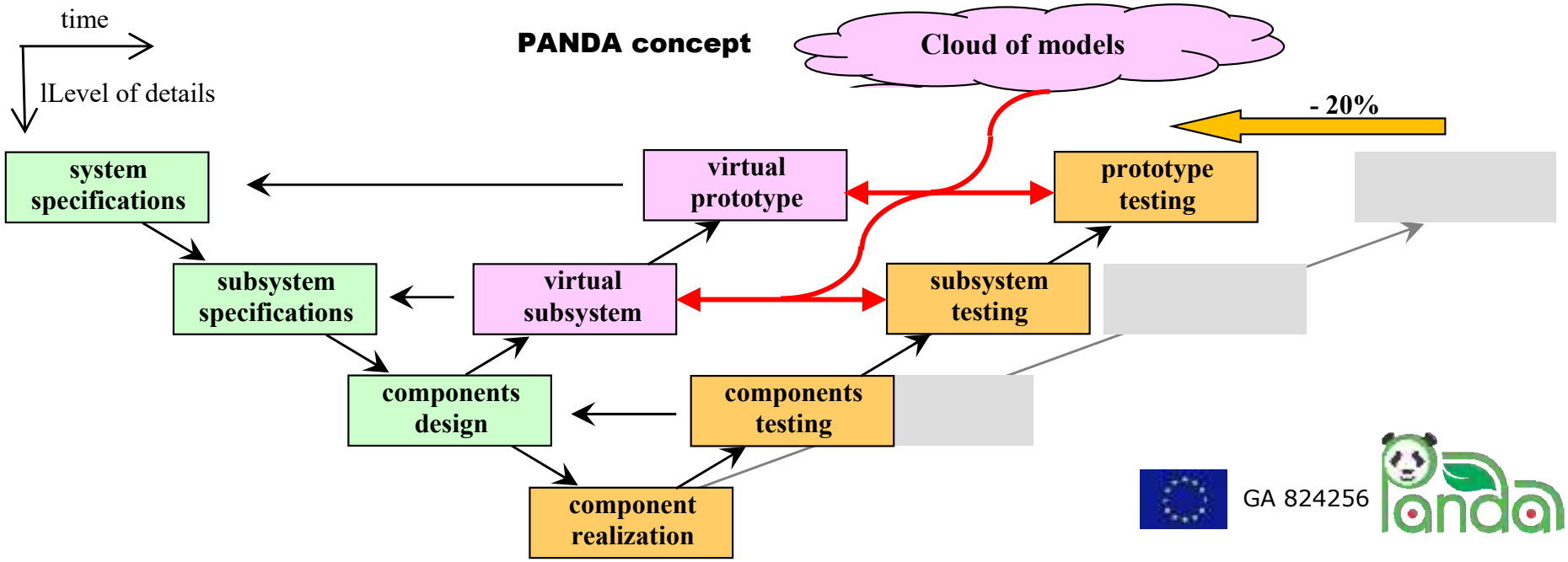
ALSTOM PSA PEUGEOT CITROËN SIEMENS SNCF

RENAULT Valeo Typhoon HIL

Application to the H2020 PANDA project

H2020 PANDA

Powerful **A**dvanced **N**-level **D**igital **A**rchitecture for models of EVs and components



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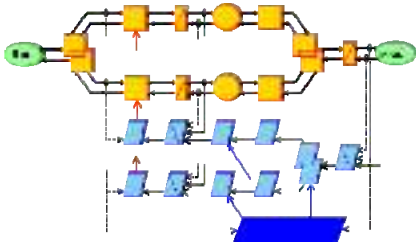
Unified model organization for virtual and real testing of electrified vehicles (**using EMR**)

PANDA developments

EMR formalism



L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

Université de Lille

Application to an industrial software

Simcenter AMESIM

SIEMENS Ingenuity for life

study cases

Electric Vehicle

Renault ZOE

RENAULT Passion for life

Fuel Cell Vehicle

MobyPost

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

Hybrid Vehicle

48V-based HEV

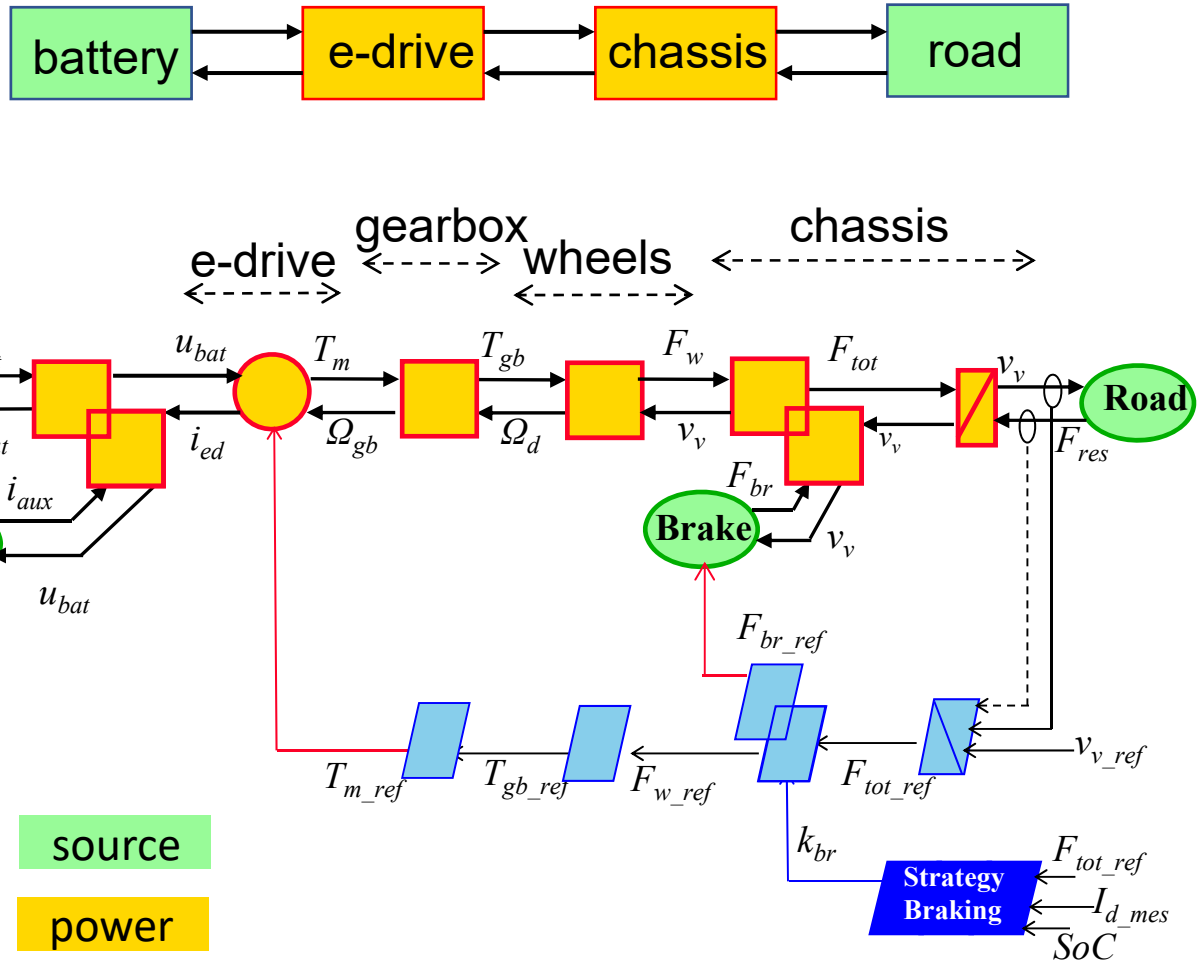
Valeo

The EMR of the studied BEV

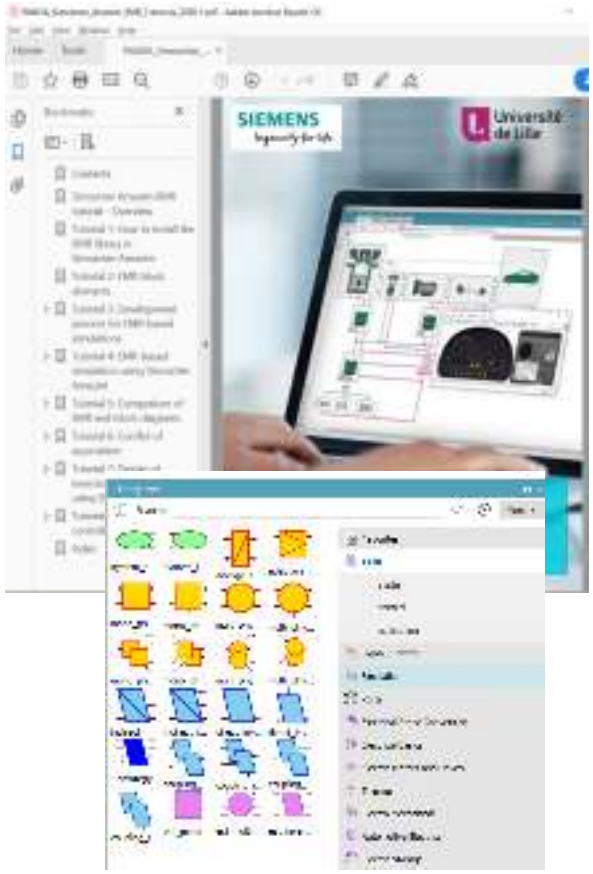
Renault ZOE

Li-Ion
41 kWh
400 V
290 kg

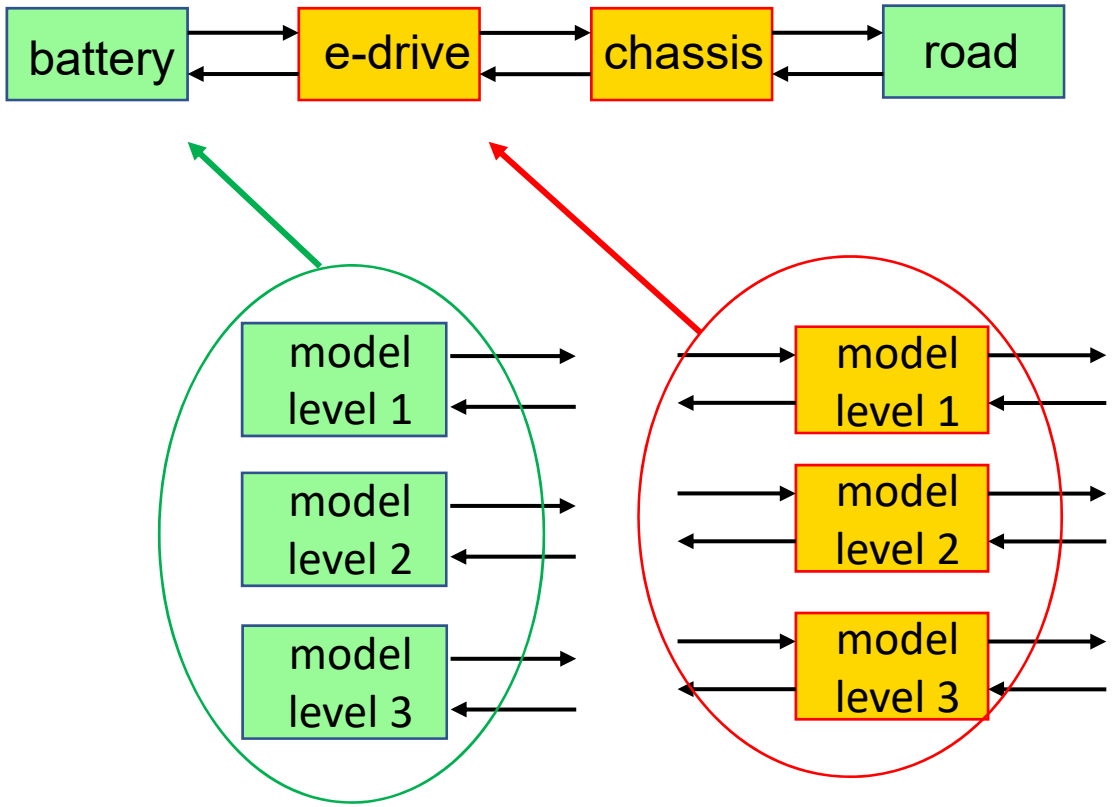
Synchronous
Machine
65 kW



Multi-level modelling simulation



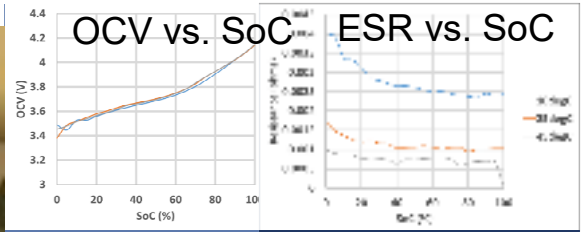
EMR library in Simcenter Amesim ©

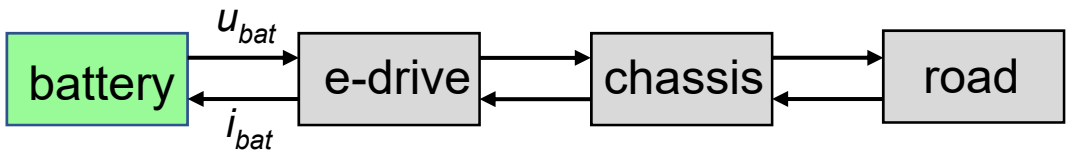


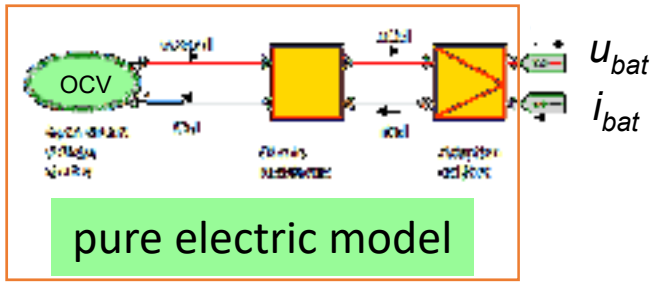
🐼 Different models can be **interchanged by "plug & play"**

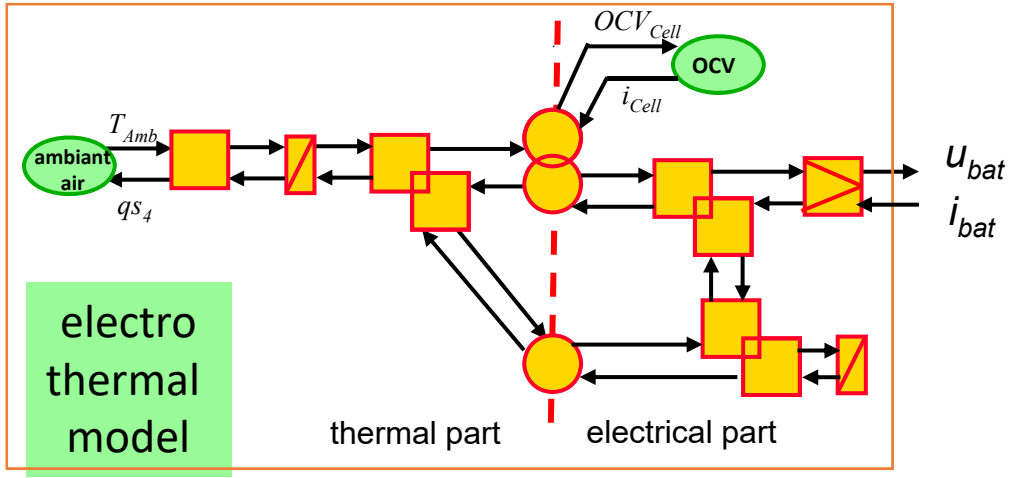
Different level of battery models

Model identifications





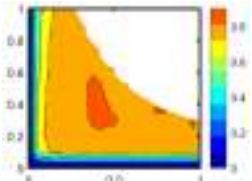


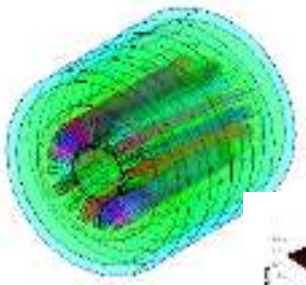


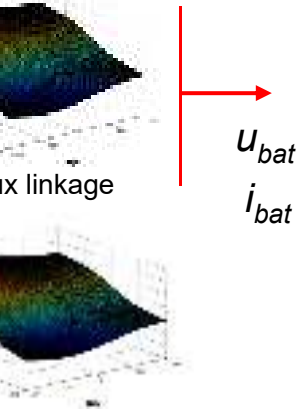
Always same Inputs / Outputs

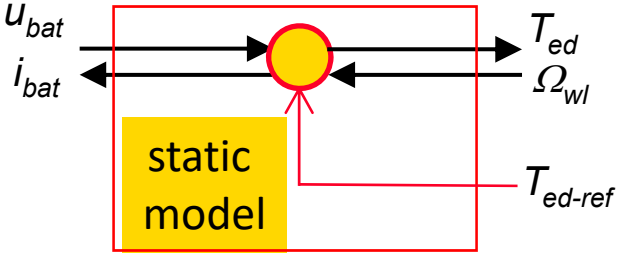
Different level of e-drive models

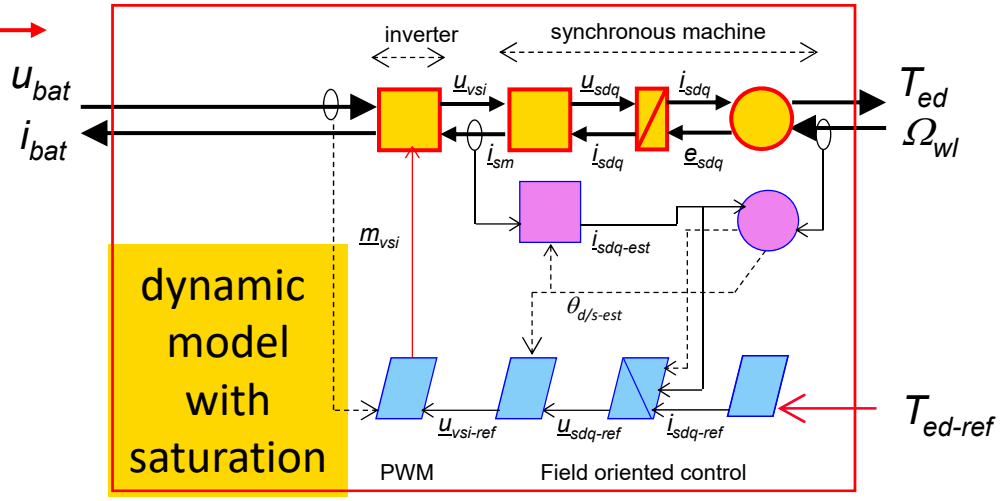
Parameter identifications











Always same Inputs / Outputs

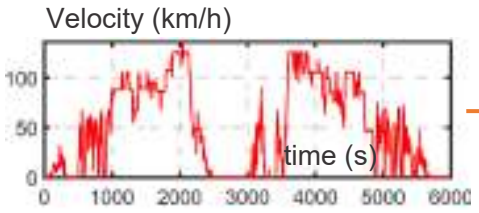
Validation of the simulation model

measurements

GROUPE RENAULT

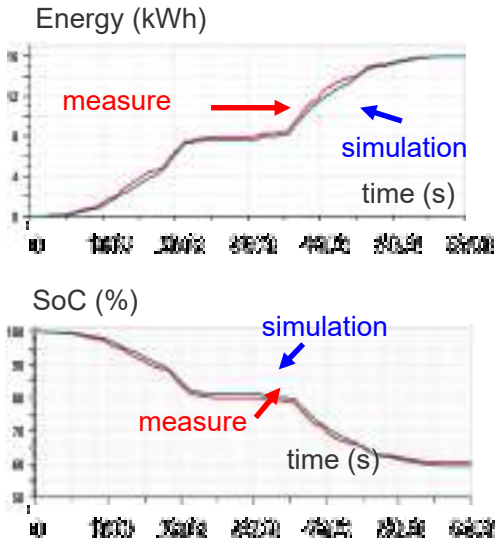
measurements

different real driving cycles
from RTR track
(Romania)



input

results



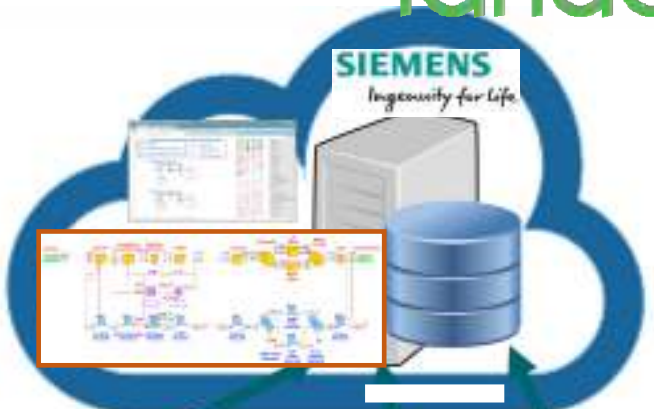
Error on energy < 2%
for different driving cycle
for different model levels

Extra-urban real
driving cycle

Simulation from the
EMR library

HIL testing of e-drive: principle

(PANDA Cloud)



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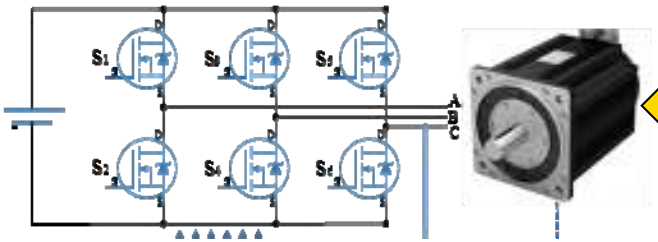
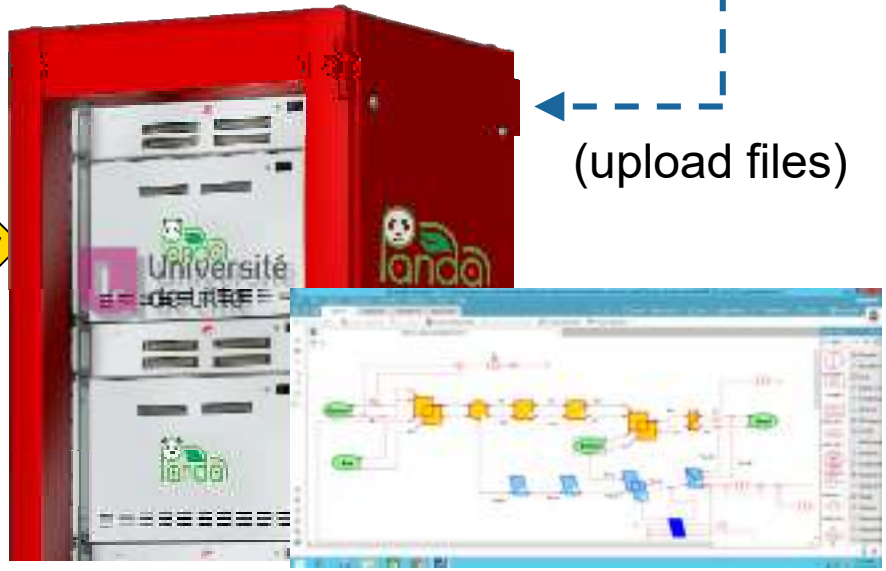
Real e-drive under test



power

Power interface & real-time simulator

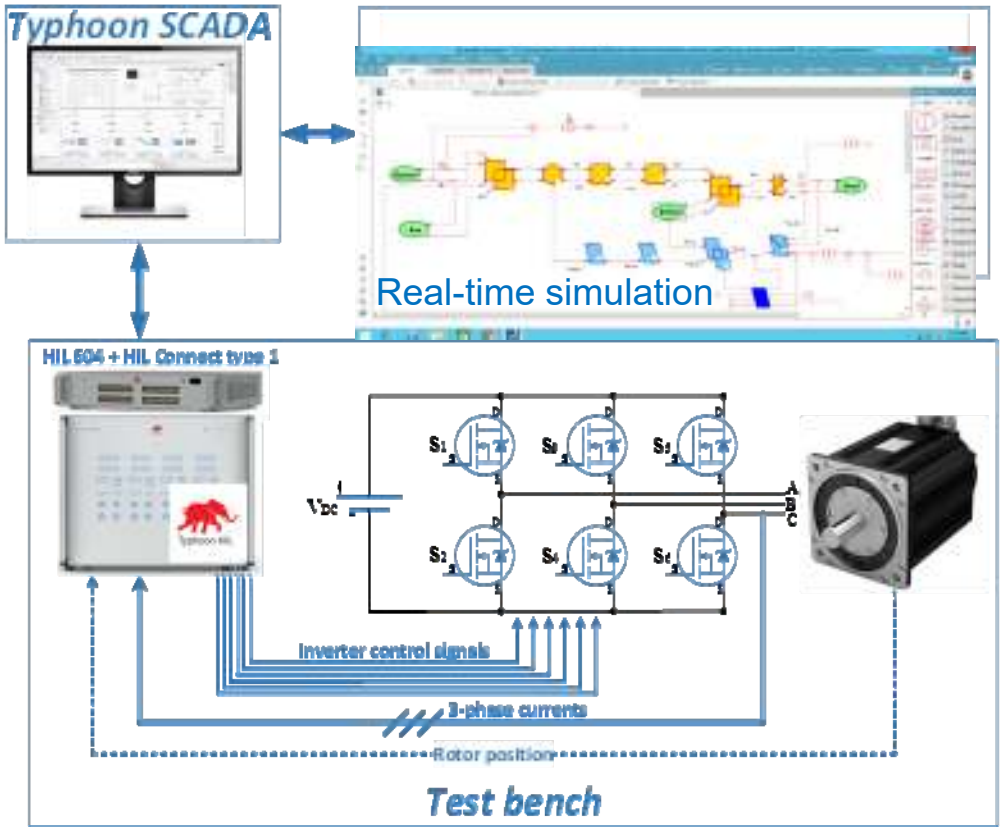
Typhoon HIL

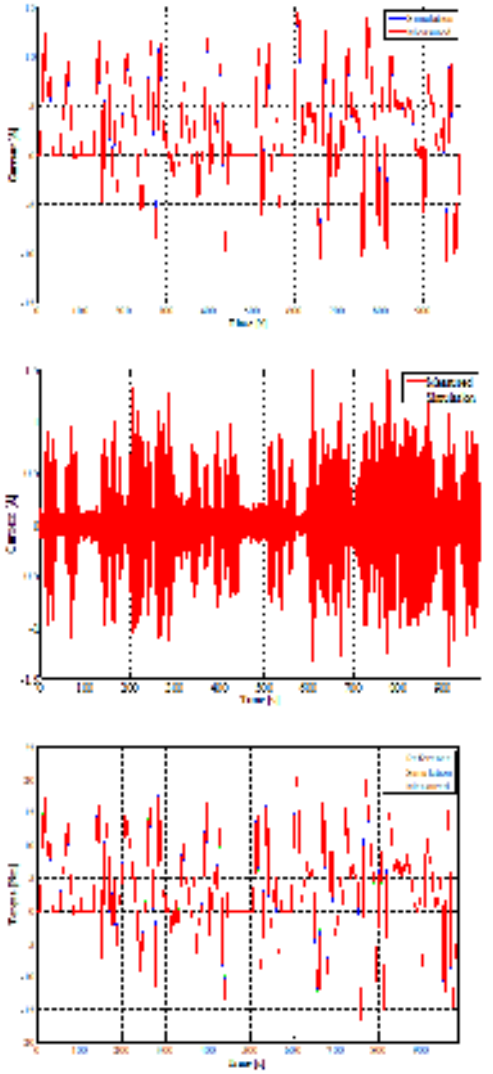


(upload files)

Real-time simulation of Renault Zoé

HIL testing of e-drive: results





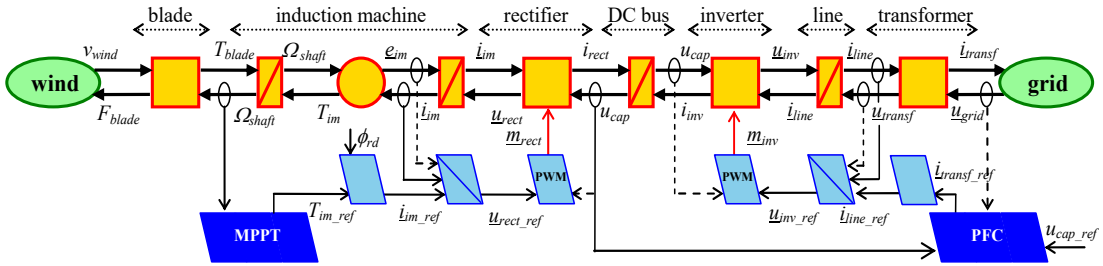
experimental results

Conclusion

It’s finished!

Conclusion

- Energy Conversion Systems are key points for sustainable development
- Innovative energy conversion systems must be developed
- EMR can be a way for a systematic control organization of energy conversion systems



EMR and control of a Wind Energy conversion System

Next international annual
EMR Summer School
Sion (Switzerland)
20-23 June 2022

EMR'19 summer school, Lille June 2019

Our PANDA
Thanks you for your attention !

H2020 PANDA project

https://project-panda.eu/

EMR formalism

http://www.emrwebsite.org/

Selected references

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