EMR'23, Lille (France)

http://emrwebsite.org

« ENERGY & SYSTEM »

Prof. Alain BOUSCAYROL

(L2EP, University of Lille, France)

Prof. C.C. CHAN

(University of Hong-Kong, China)

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

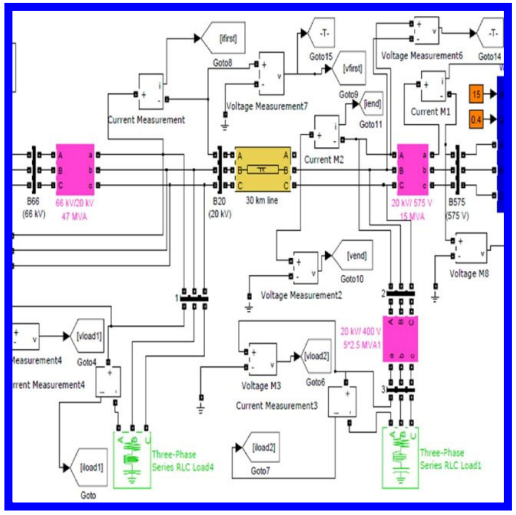
Université de Lille

SAPIENTIA·ET·VIRTUS

Simulation as a magic tool?

real system

simulation



results

Fast development
with "copy & paste"

Nightmare
for finding errors

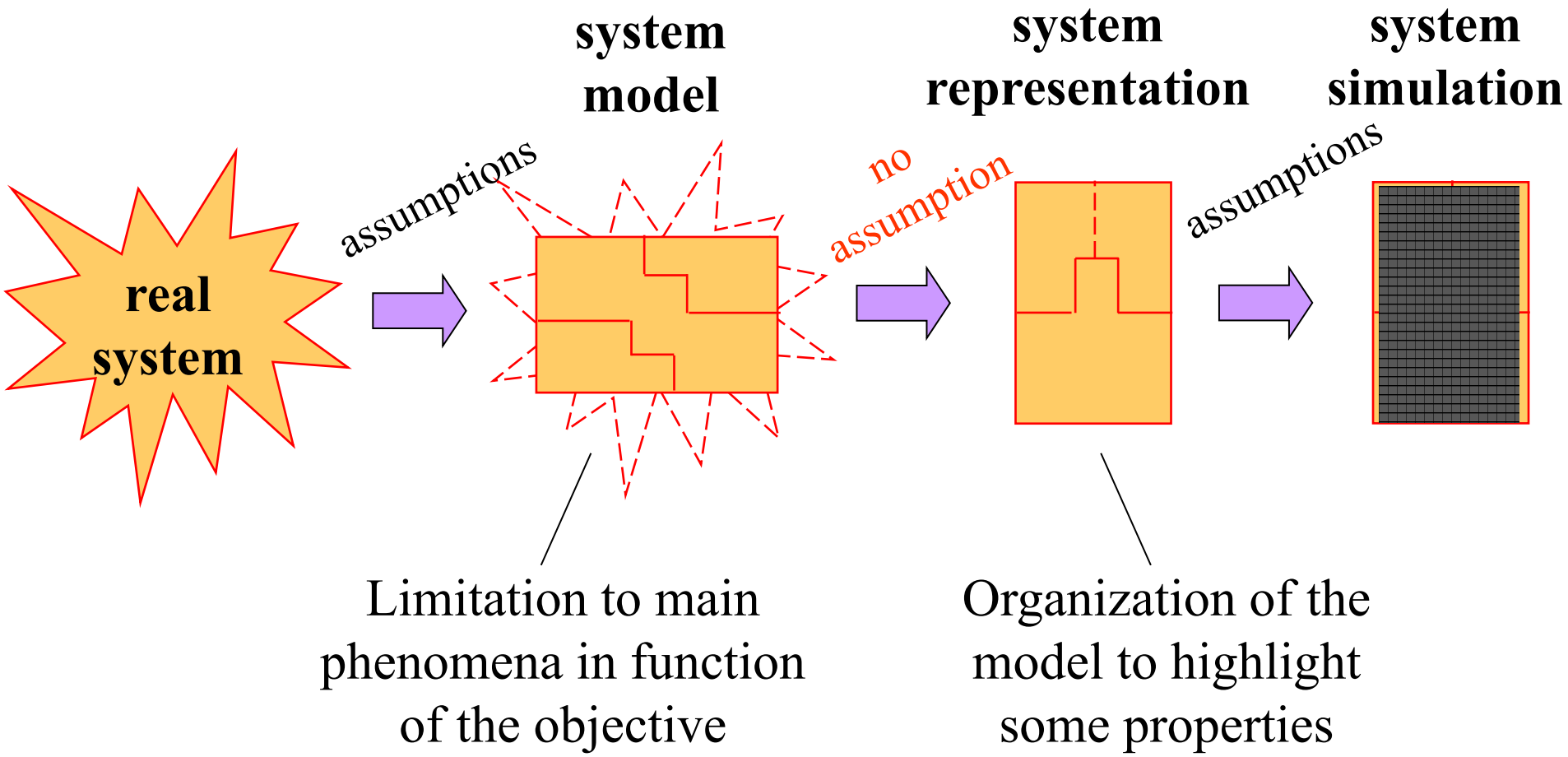
confidence?
accuracy?

- Outline -

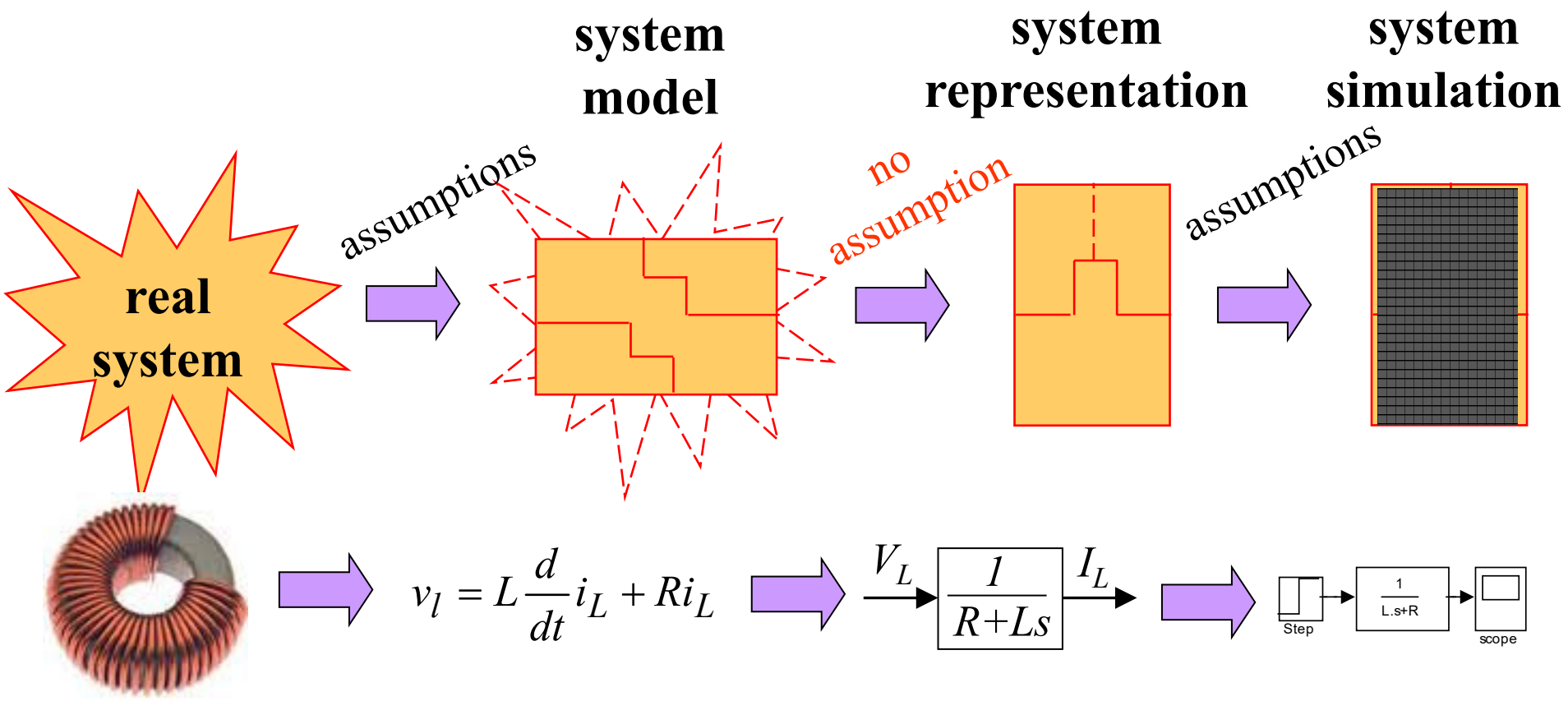
1. **Model, Representation, Simulation**
2. **System & Interaction**
3. **Energy & Causality**
4. **Graphical descriptions**

« 1. Model, Representation and Simulation »

What different steps before simulation?



Intermediary steps are required for complex systems



smoothing inductor

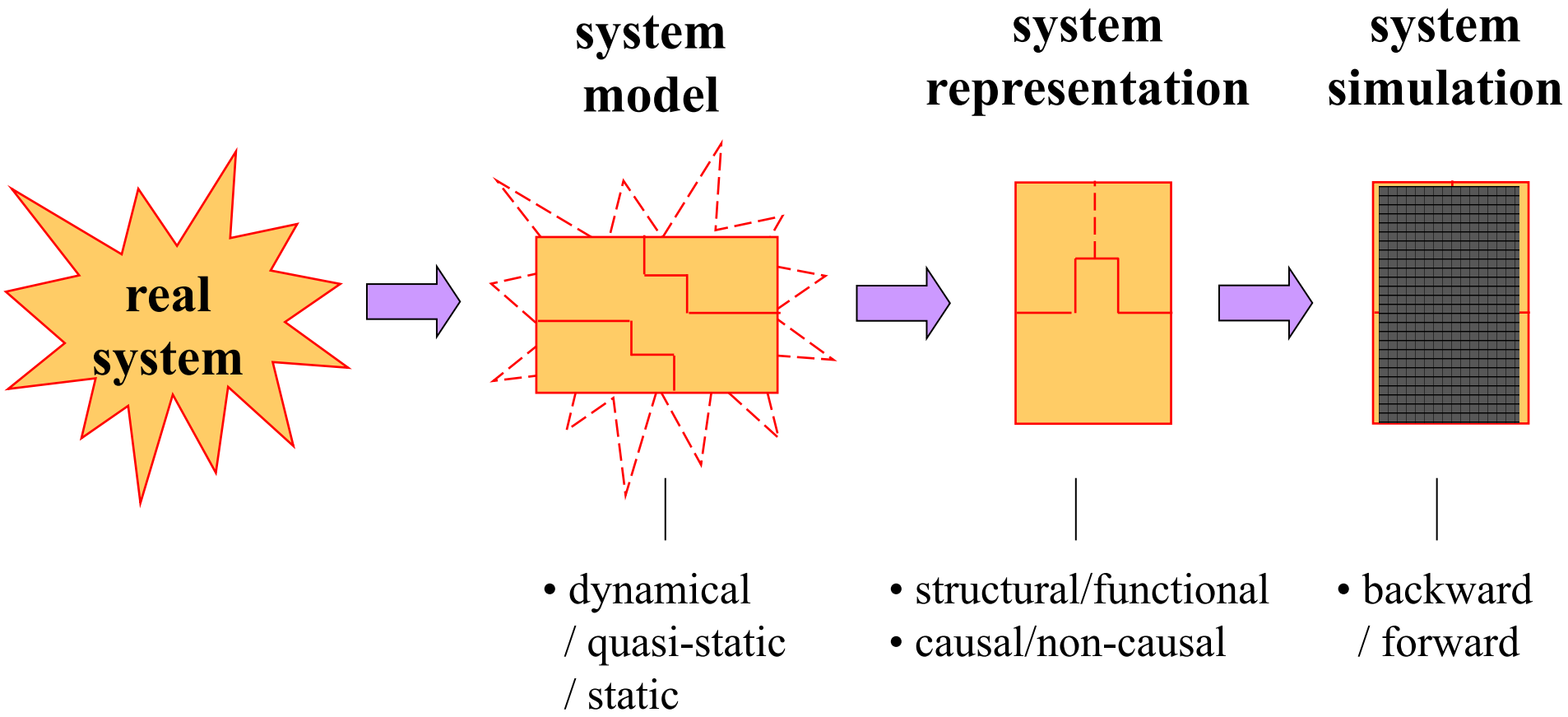
(low frequency dynamical model)

(bloc diagram +Laplace)

(Simulink © +Range Kutta)

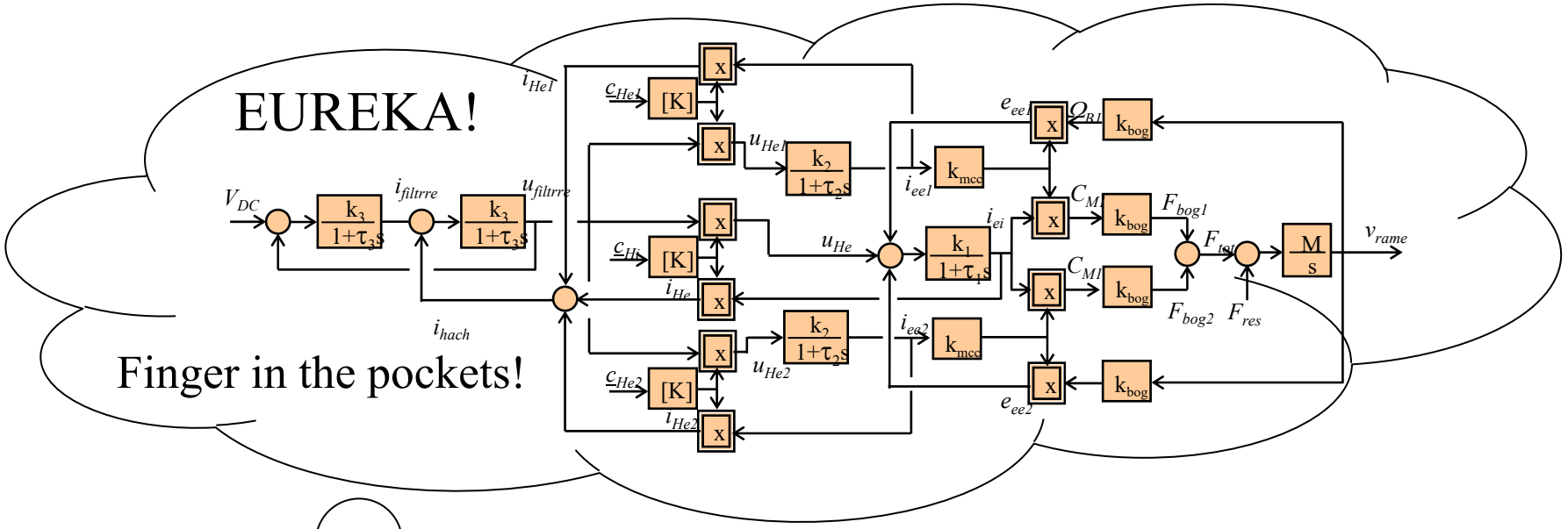
Different possibilities at each step in function of the objective

- Different categories -



Different possibilities at each step in function of the objective

- Limitation of classical bloc diagrams -



Remember,
See the wood before the trees!

But block diagrams:

- can be confusing for complex systems
- are limited to continuous and linear systems
- do not highlight energy properties
- do not highlight interaction between subsystems

« 2. System & Interaction »

How to connect multi-physical subsystems?

System = interconnected subsystems
organized for a common objective,
in interaction with its environment

Systemic = science of study of systems and their interactions

Cartesian approach = the study of subsystems is sufficient to know the system behavior (without considering their interactions)

Interactions is the keyword

System = interconnected subsystems

Systemic approach
Study of subsystems and their interactions
Holistic property: associations of subsystem induce new global properties.

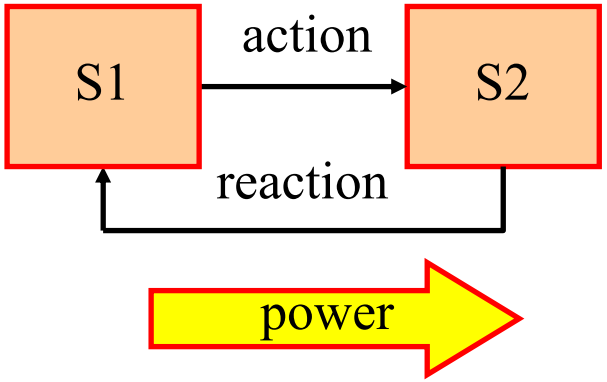
Cartesian approach
The study of subsystems is sufficient to know the system behaviour.

Cybernetic systemic
black box approach.
behaviour model

Cognitive systemic
physical laws
knowledge model

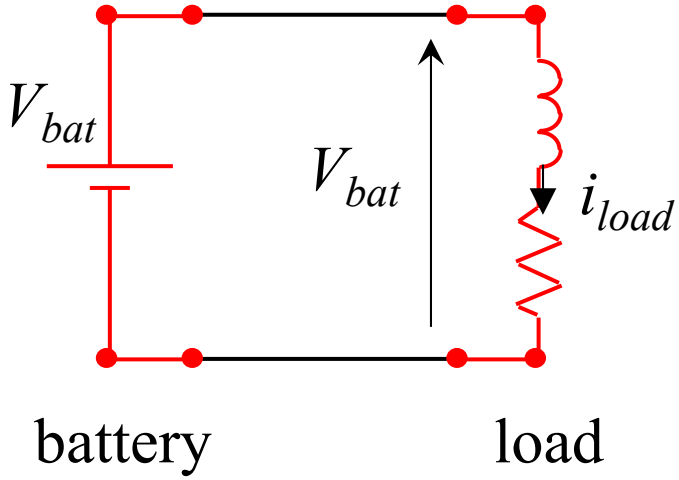
For better performances of a system
Interactions and physical laws must be considered!

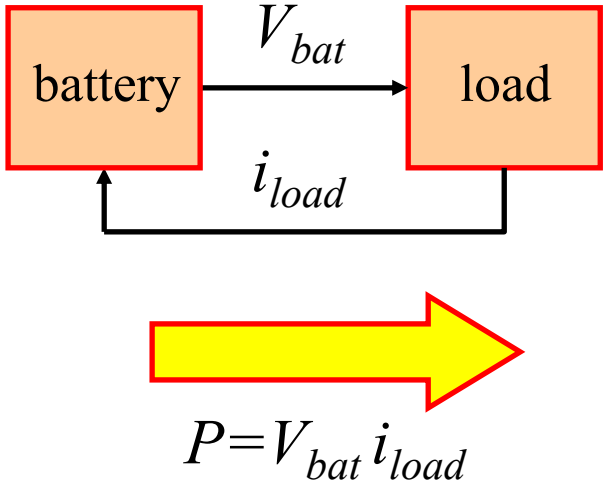
Interaction principle
Each action induces a reaction



Power exchanged by S1 and S2 = action x réaction

Example



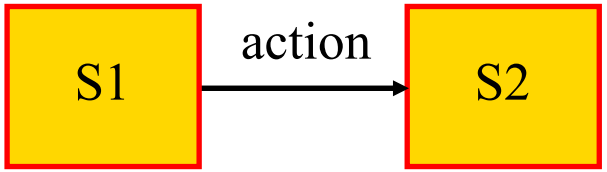


- Interaction mistake -

If the interaction principle is not respected for 1 subsystem

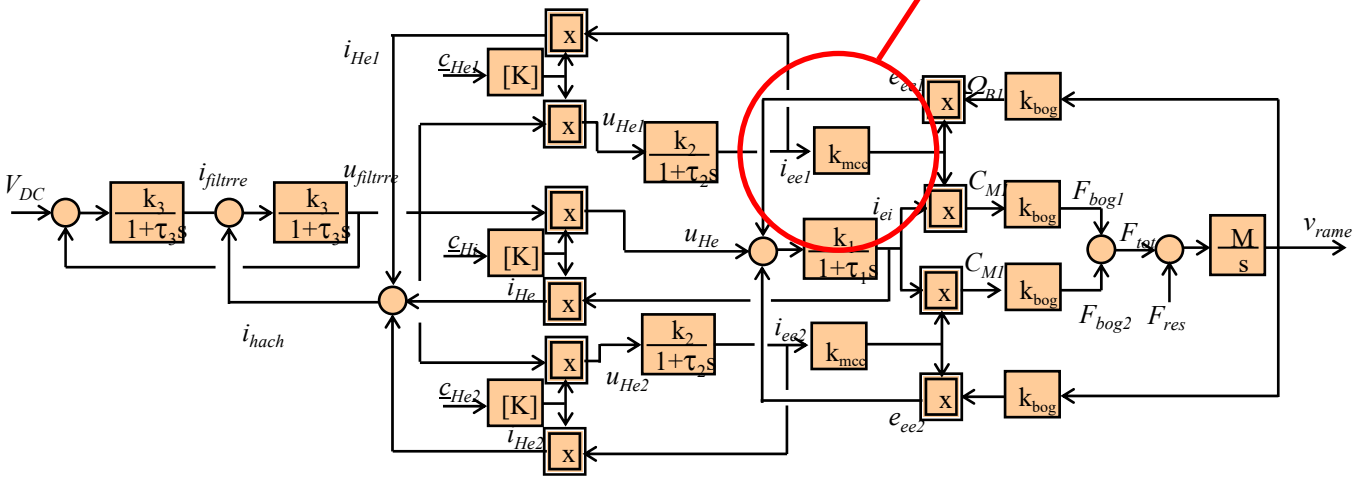
⇩

Error in the energy analysis for the whole system



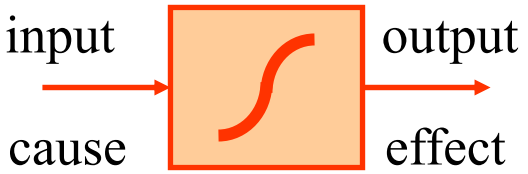
(reaction = 0)

Power = 0



« 3. Energy & Causality »

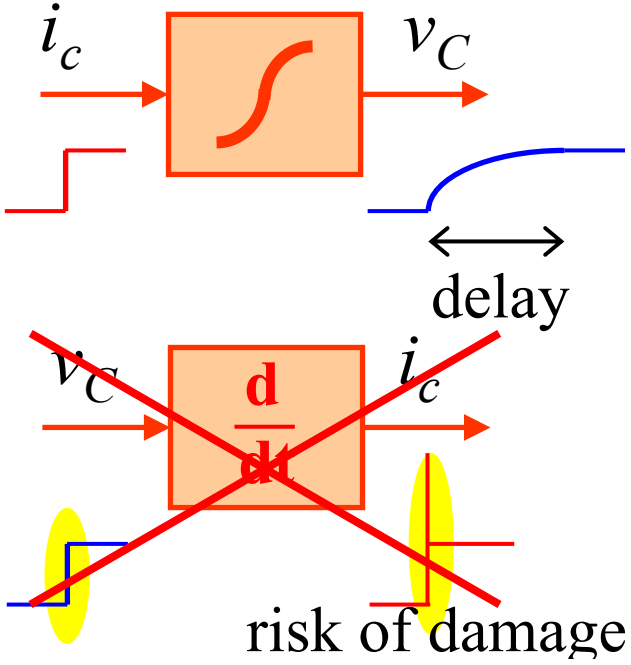
How to manage energy in the best way?



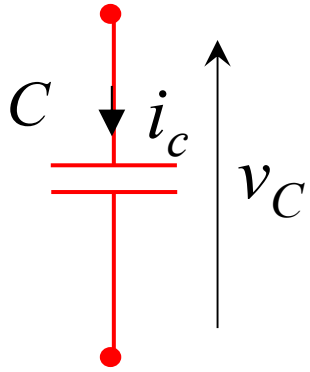
Principle of causality

Different meaning in different domains:

- Physics: output is obtained from input after a delay
- Mathematics: output is an integral function of input
- Automatic control: output is the state variable
- Energy: output is the energetic variable



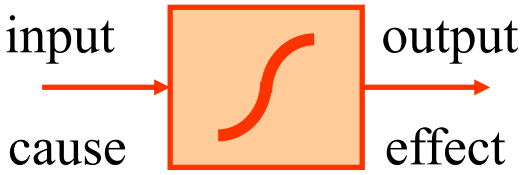
Example

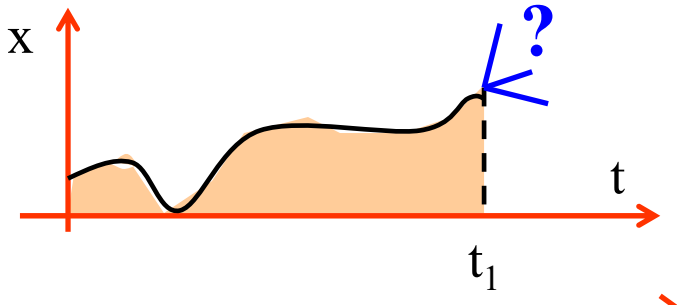


$$i_c = C\frac{d}{dt}v_c + \frac{v_c}{R}$$

$$E_c = \frac{1}{2}v_c^{\,2}$$

Principle of causality
physical causality is integral





$\int x dt$ ⇨ area

OK in real-time

⇩

knowledge of past evolution

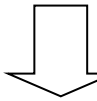
impossible in real-time

slope ⇦ $\frac{dx}{dt}$

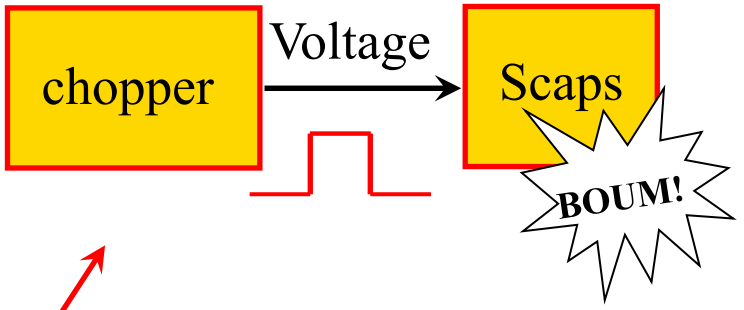
⇩

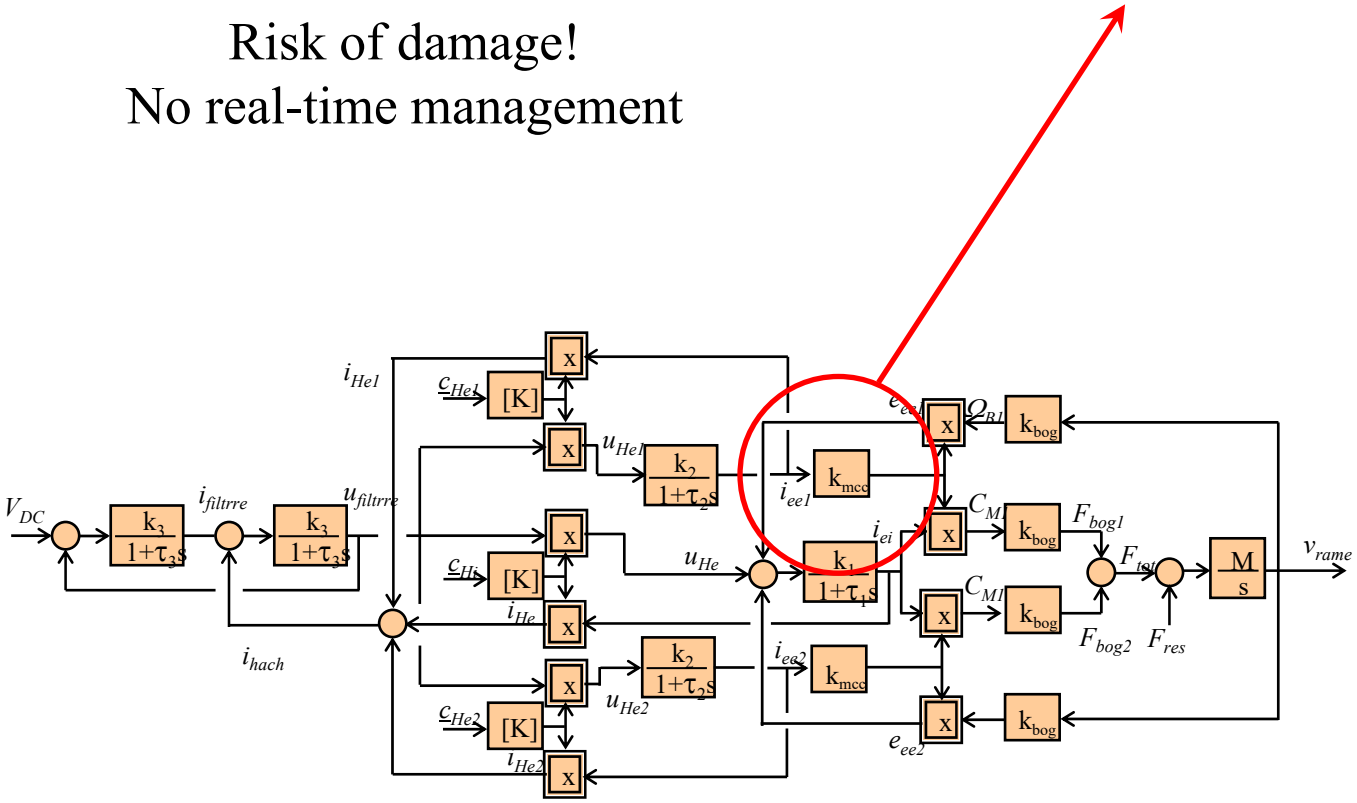
knowledge of future evolution

If the causality principle is not respected for 1 subsystem



Risk of damage!
No real-time management

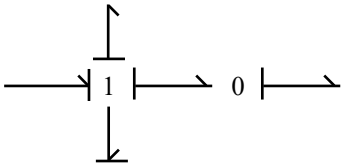




« 4. Graphical descriptions »

Interest of graphical desciptions?

Energy & System



Energetic Puzzles (Laplace, France)

Bond Graph (USA, The Netherlands…)

Power Oriented Graph (Italy)

Signal Flow Diagram (Germany, Japan...)

Structural description for analysis and design ⇨ mathematical model ⇩ global controls

Block diagrams
COG (L2EP-LEEI, France)

EMR (L2EP, France)

functional descriptions for simulation and control ⇨ inversion graphs ⇩ cascaded control

Remember,
divide and conquer!

CONCLUSION

How to model and control energy conversion systems ?

- Respect the interaction principle (System) ?
- Respect of the causality principle (Energy) ?
- Multi-domain systemics approach ?
- Common language ?

EMR as a guideline !

Alain.Bouscayrol@univ-lille.fr

Prof. Alain BOUSCAYROL, University of Lille, L2EP,
Head of the Master "Automatic control & Electrical Systems"
Coordinator of the CUMIN interdisciplinary programme
Coordinator of the PANDA European project
Chair of the steering committee of IEEE-VPP Ccnference of IEEE-VTS
PhD in Electrical Engineering at University of Toulouse (1995)
Research topics: EMR formalism, HIL testing, control & EV-HEVs

Prof. C.C. Chan
The University of Hong-Kong, China
Fellow, Royal Academy of Engineering, U.K.
Academician, Chinese Academy of Engineering
President, Electric Vehicle Association of Asia Pacific
Honorary Professor, University of Hong Kong²

S. Astier, A. Bouscayrol, X. Roboam, "Introduction to Systemic Design", *Systemic Design Methodologies for Electrical Energy, tome 1, Analysis, Synthesis and Management*, Chapter 1, ISTE Willey editions, October 2012, ISBN: 9781848213883

A. Bouscayrol, J. P. Hautier, B. Lemaire-Semail, "Graphic Formalisms for the Control of Multi-Physical Energetic Systems", *Systemic Design Methodologies for Electrical Energy*, tome 1, Analysis, Synthesis and Management, Chapter 3, ISTE Willey editions, October 2012, ISBN: 9781848213883.

A. Bouscayrol, B. Lemaire-Semail, "Energetic Macroscopic Representation and Inversion-Based Control ", Encyclopedia of electrical and electronic power engineering, Vol. 3, pp 365-375, Elesevier, DOI : 10.1016/B978-0-12-821204-2.00117-3, ISBN : 978-0-12-823211-8, 2023.

C.C. Chan, A. Bouscayrol, K. Chen, "Philosophy of Engineering and Modelling of Electric Drives", International Conference on Electrical, Keynote, October 2008, Wuhan (China)

C. C. Chan, A. Bouscayrol, K. Chen, "Electric, Hybrid and Fuel Cell Vehicles: Architectures and Modeling", IEEE transactions on Vehicular Technology, vol. 59, no. 2, February 2010, pp. 589-598 (L2EP Lille and Honk-Kong Univ).

J. P. Hautier, P. J. Barre, "The causal ordering graph - A tool for modelling and control law synthesis", *Studies in Informatics and Control Journal,* vol. 13, no. 4, December 2004, pp. 265-283.

H. Paynter, "Analysis and design of engineering systems", *MIT Press,* 1961.