

**EMR'23, Lille (France)**

<http://emrwebsite.org>

# «EMR-based simulation using Simcenter Amesim»

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<sup>2</sup> L2EP, University of Lille, France



- 1 **Simcenter Amesim software**
- 2 **EMR library into Simcenter Amesim**
- 3 **Structural vs. Functional representation**
- 4 **Panda EMR simulations**



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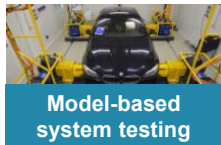
**« Simcenter Amesim »**

# EMR-based simulation using Simcenter Amesim

## - Simcenter Amesim -

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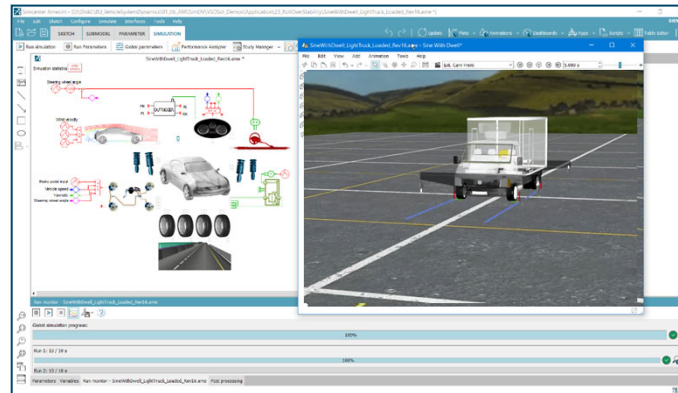


**Model-based system testing**

**Industry specific**

- Vehicle integration
- Vehicle electrification
- ADAS and autonomous vehicle
- Powertrain controls
- Engine design
- Aftertreatment
- Transmission
- HVAC
- Engine thermal management
- Vehicle dynamics
- Powertrain subsystems

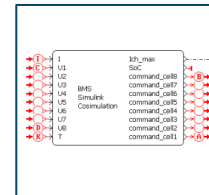
**Pre-design**  
**Systems sizing and integration**  
**Performance balancing**  
**Controls validation**



**Scalable simulation**

**Connecting “mechanical” – “controls”**

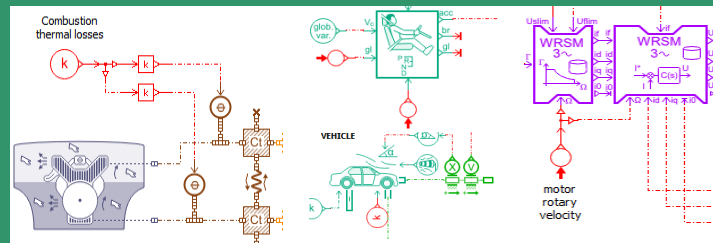
**Model reduction for real-time**



**Co-simulation**

**Open and customizable**

**>48 libraries**  
**>6,500 multi-physics models**



**Hydraulics**  
**Pneumatics**  
**Thermal**  
**Electrical**  
**Mechanical Signals**

System	Component	Model Name	Library	Part Name
U1	Simulink	command_cell1	Simulink	command_cell1
U2	Simulink	command_cell2	Simulink	command_cell2
U3	Simulink	command_cell3	Simulink	command_cell3
U4	Simulink	command_cell4	Simulink	command_cell4
U5	Simulink	command_cell5	Simulink	command_cell5
U6	Simulink	command_cell6	Simulink	command_cell6
U7	Simulink	command_cell7	Simulink	command_cell7
U8	Simulink	command_cell8	Simulink	command_cell8
U9	Simulink	command_cell9	Simulink	command_cell9
U10	Simulink	command_cell10	Simulink	command_cell10
U11	Simulink	command_cell11	Simulink	command_cell11
U12	Simulink	command_cell12	Simulink	command_cell12
U13	Simulink	command_cell13	Simulink	command_cell13
U14	Simulink	command_cell14	Simulink	command_cell14
U15	Simulink	command_cell15	Simulink	command_cell15
U16	Simulink	command_cell16	Simulink	command_cell16
U17	Simulink	command_cell17	Simulink	command_cell17
U18	Simulink	command_cell18	Simulink	command_cell18
U19	Simulink	command_cell19	Simulink	command_cell19
U20	Simulink	command_cell20	Simulink	command_cell20
U21	Simulink	command_cell21	Simulink	command_cell21
U22	Simulink	command_cell22	Simulink	command_cell22
U23	Simulink	command_cell23	Simulink	command_cell23
U24	Simulink	command_cell24	Simulink	command_cell24
U25	Simulink	command_cell25	Simulink	command_cell25
U26	Simulink	command_cell26	Simulink	command_cell26
U27	Simulink	command_cell27	Simulink	command_cell27
U28	Simulink	command_cell28	Simulink	command_cell28
U29	Simulink	command_cell29	Simulink	command_cell29
U30	Simulink	command_cell30	Simulink	command_cell30

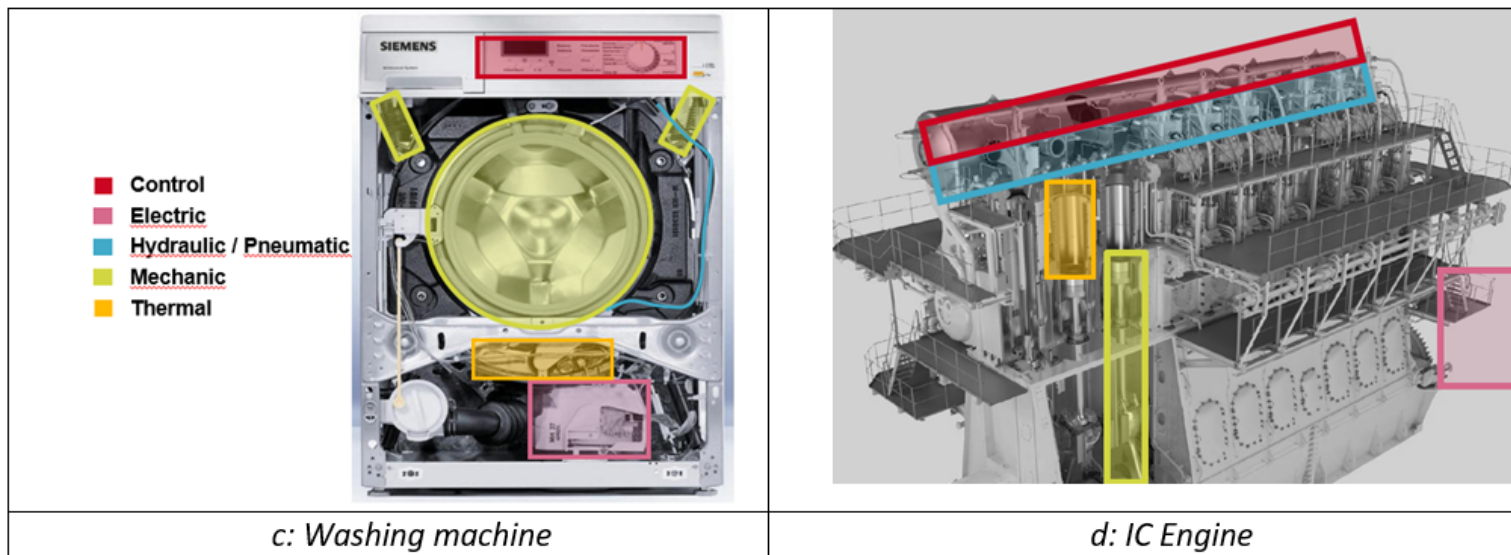
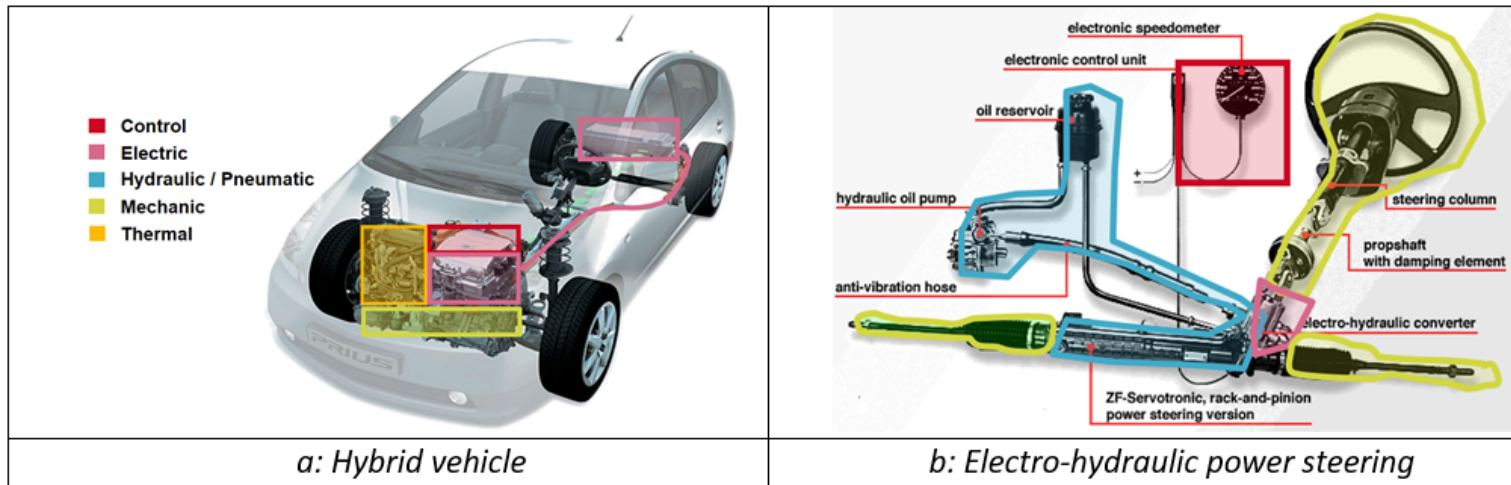
**System architecture management**

# EMR-based simulation using Simcenter Amesim

## - Simcenter Amesim mechatronic systems -

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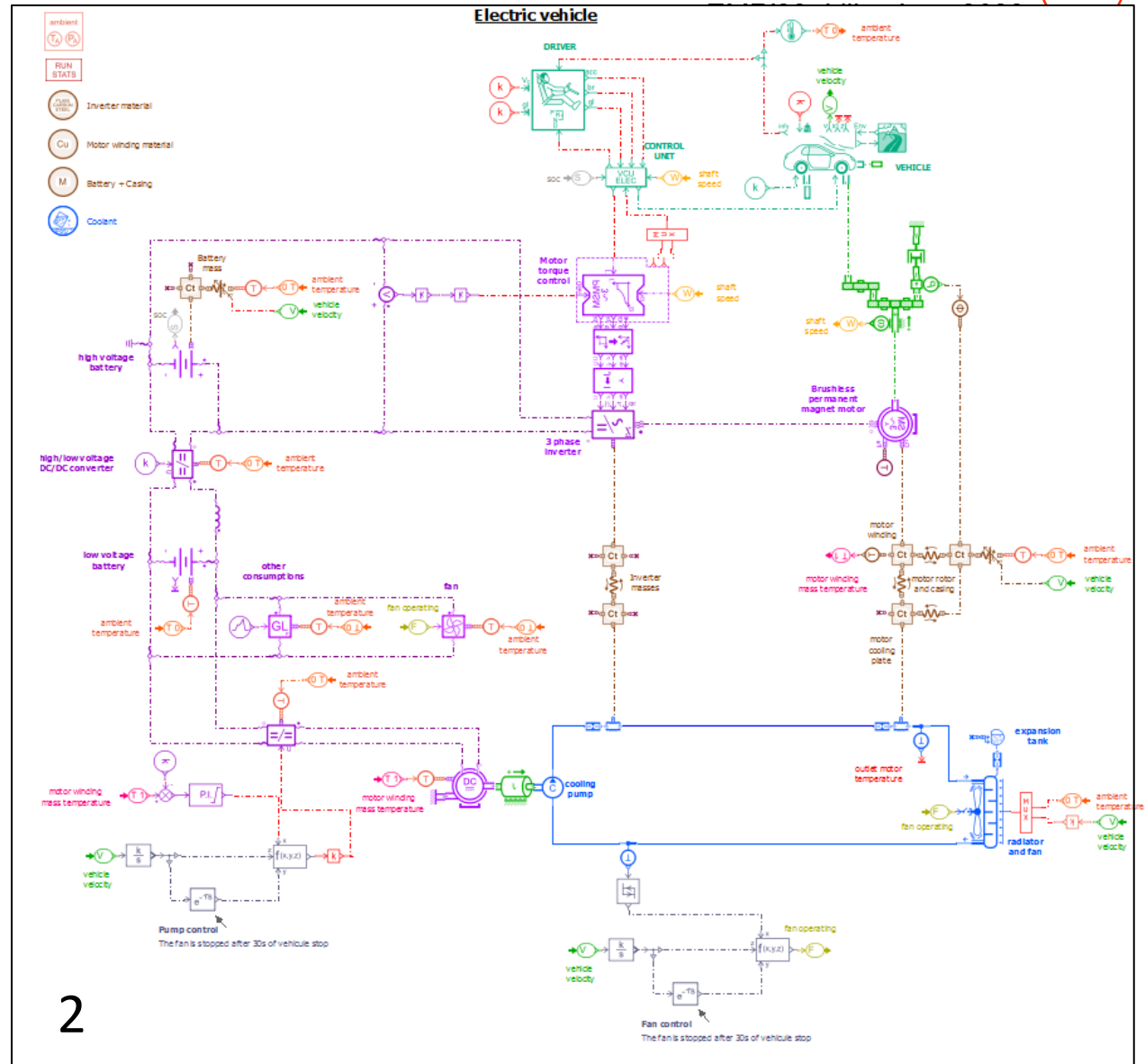
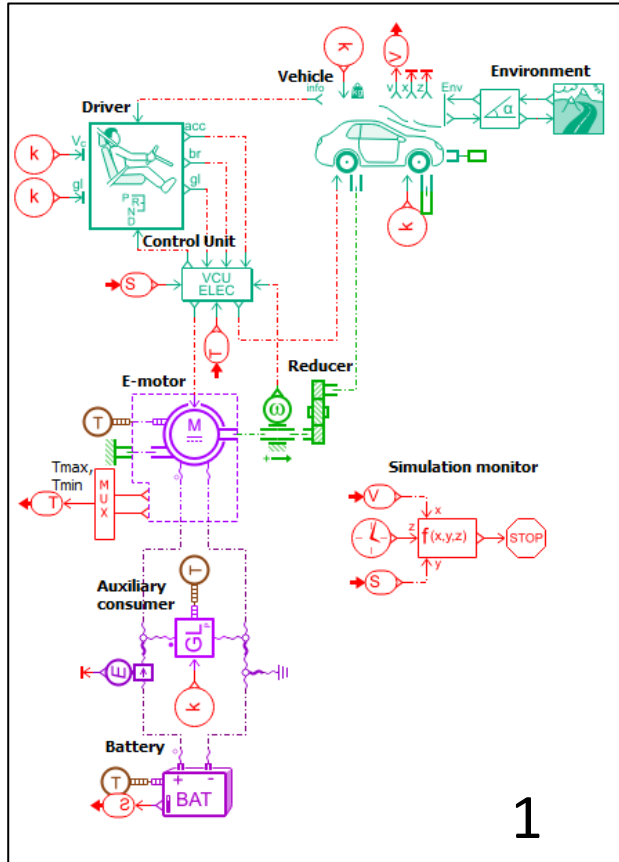
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# EMR-based simulation using Simcenter Amesim

## - Simcenter Amesim – Electric Vehicles -

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**«EMR library into Simcenter Amesim»**

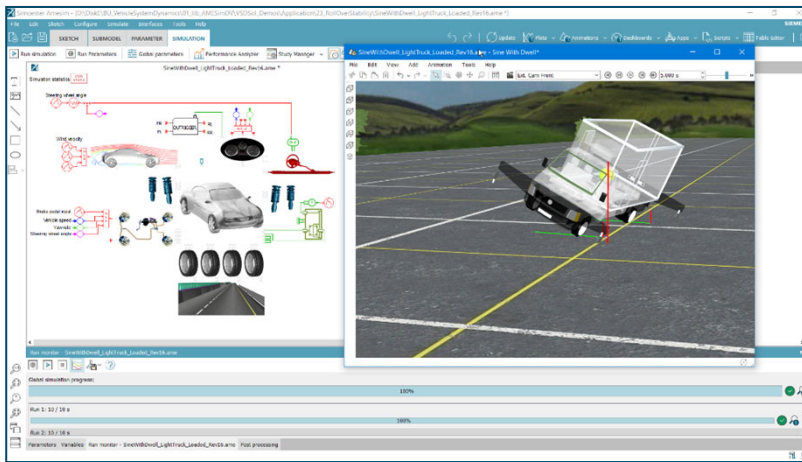


# EMR-based simulation using Simcenter Amesim

## - Simcenter Amesim - New EMR library-

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Pre-design

Systems sizing & integration

Performance balancing

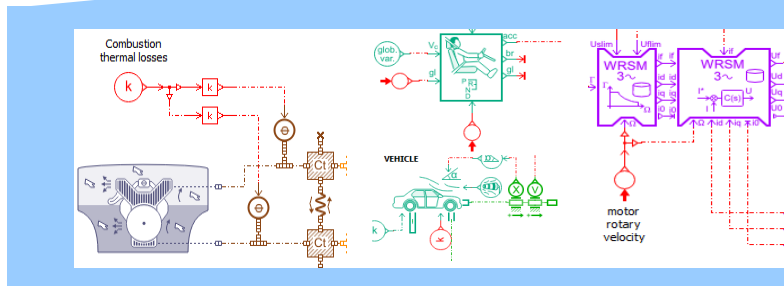
Controls validation

Advanced industrial  
Multiphysics simulation  
package

based on  
**structural libraries**  
for models  
and  
a functional library  
for control



new **EMR-based**  
functional library  
for models  
& control



**48 libraries**  
**(6500 models)**

- Hydraulics
- Pneumatics
- Thermal
- Electrical
- Mechanical
- Signals, etc.



# EMR-based simulation using Simcenter Amesim

## - Simcenter Amesim EMR library -

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🐼 **New and dedicated EMR library** where all components defined by EMR theory are included

🐼 **Help module** with the description of each EMR element and new developed EMR tutorials included

PANDA\_Simcenter\_Amesim\_EMR\_Tutorials\_2020.1.pdf - Adobe Acrobat Reader DC

File Edit View Window Help

Home Tools PANDA\_Simcenter\_...

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Bookmarks

- Contents
- Simcenter Amesim EMR tutorial - Overview
- Tutorial 1: How to install the EMR library in Simcenter-Amesim
- Tutorial 2: EMR block elements
- Tutorial 3: Development process for EMR-based simulations
- Tutorial 4: EMR-based simulation using Simcenter Amesim
- Tutorial 5: Comparison of EMR and block diagrams
- Tutorial 6: Conflict of association
- Tutorial 7: Design of inversion-based control using EMR
- Tutorial 8: Tuning of controllers
- Index

SIEMENS Ingenuity for Life

Université de Lille

Simcenter Amesim EMR tutorial

Library tree

Search:

system... system... system... system... energy... adaptio... mono\_p... mono\_p... multi\_p...

multi\_p... switchin... mono\_p... mono\_p... mono\_p... multi\_p... multi\_p... multi\_p... indirect...

indirect... direct\_j... direct\_j... direct\_j... switchin... couplin... couplin... couplin... couplin...

couplin... strategy system... system... system... system... energy... adaptio... mono\_c...

mono\_c... multi\_c... multi\_c... switchin... mono\_d... mono\_d... mono\_d... multi\_d... multi\_d...

multi\_d... est\_mo... est\_mul... est\_inv...

Favorites

Simulation

Ports

Signal, Control

EMR

- system
- control
- estimation
- 1D Mechanical
- Hydraulic
- Discrete Partitioning
- Hydraulic Component Design
- Hydraulic Resistance

Simcenter Amesim - [unnamed\_system]

File Edit Sketch Configure Simulate Interfaces Tools Help

## EMR Help module

### Energetic Macroscopic Representation Library

Description

EMR is a systemic extension of COG (Casual Ordering Graph), based on the interaction principle.

Documentation

Components list	Tutorials
-----------------	-----------

# EMR-based simulation using Simcenter Amesim

## EMR simulations in Simcenter Amesim

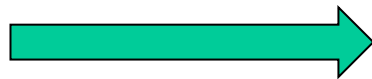
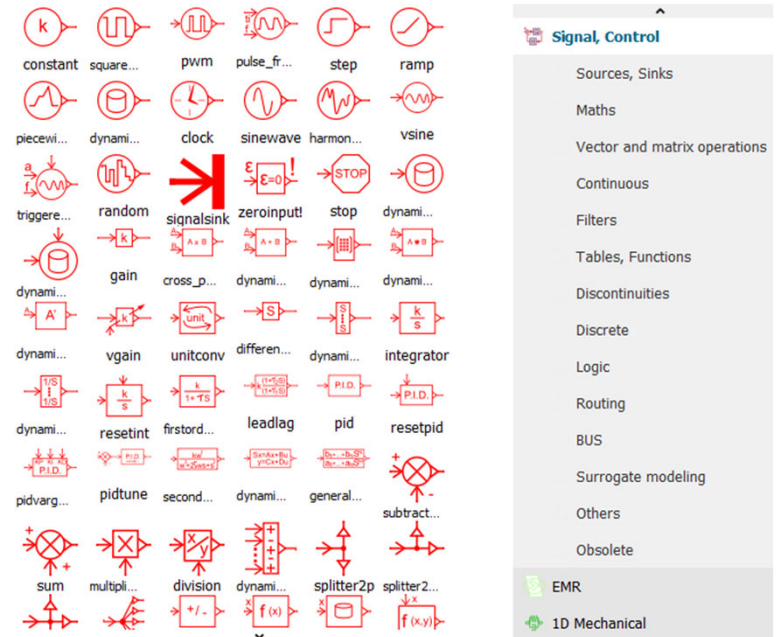
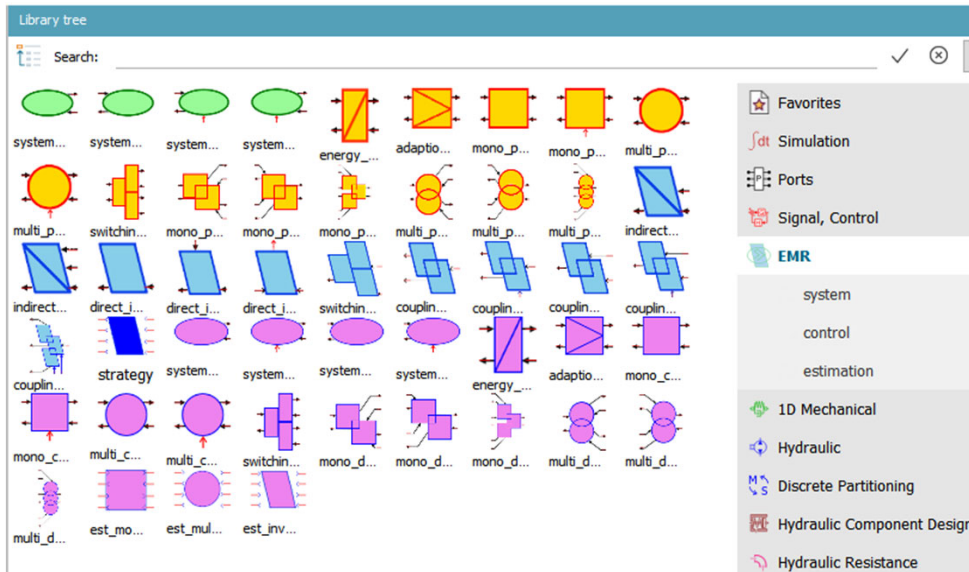
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New EMR library



Signal & Control library



EMR simulations in Simcenter Amesim

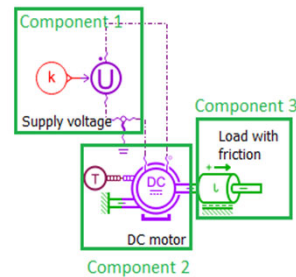
# EMR-based simulation using Simcenter Amesim

## Development process for EMR simulations into Simcenter Amesim

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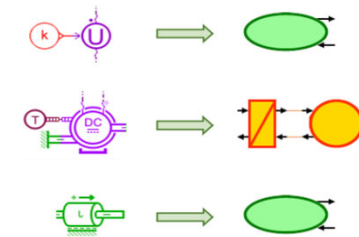
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**Step 1.**  
Definition of the different subsystems to be considered



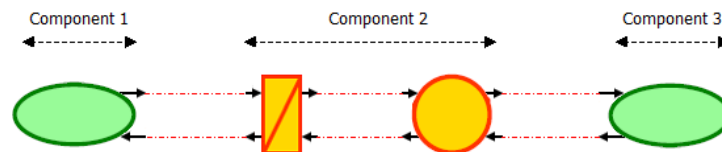
System level choice

**Step 2.**  
Definition of the equivalent EMR elements



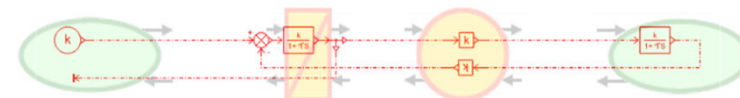
Component models vs. EMR elements

**Step 3.**  
Interconnection of the EMR elements while resolving the conflict of association



EMR diagram

**Step 4.**  
Integration of the model equation in the EMR element using the Signal and Control library



Equation model



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# **«Structural vs. Functional representation »**

# EMR-based simulation using Simcenter Amesim

## - Spring - Mass - Damper system -

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**Input: Force**      **Output: velocity**

Mass = 1 kg  
 Spring stiffness = 100 000 N/m  
 Damper rating = 1000 N/(m/s)

**MECMAS21**  
1D translation mass

For variables which have a direction associated with them, a positive sign is in the direction of the arrow.

sign reversed duplicate of velocity at port 1	→ m/s
sign reversed duplicate of displacement at port 1	← m
sign reversed duplicate of acceleration at port 1	← m/s/s
force at port 2	→ N

velocity at port 1 → m/s  
 displacement at port 1 → m  
 acceleration at port 1 → m/s/s  
 force at port 1 ← N

**SD0000A**  
mechanical spring and damper (no states)

For variables which have a direction associated with them, a positive sign is in the direction of the arrow.

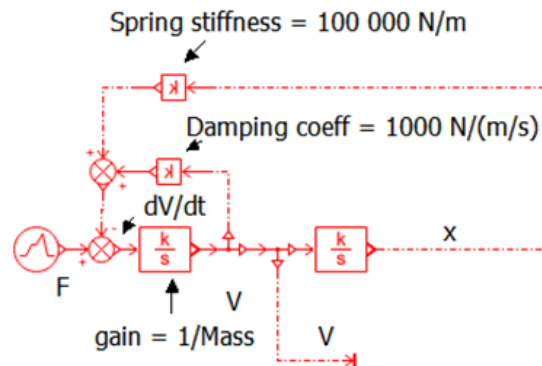
force at port 1	← N
velocity at port 1	→ m/s
duplicate of force at port 1	→ N
velocity at port 2	→ m/s
displacement at port 1	→ m
displacement at port 2	← m

Title	Value	Unit	Tags	Name
Ⓢ velocity at port 1	1	m/s		v1
Ⓢ displacement at port 1	0	m		x1
use friction	no			useFriction
endstop type	none			stoptype
mass	100	kg		mass
inclination (+90 port 1 lowest, -90 por...	0	degree		theta

Title	Value	Unit	Tags	Name
spring stiffness mode	numerical value			stiffmode
spring force with both displacements...	0	N		force0
spring rate	100000	N/m		srate
damper rating	100	N/(m/s)		cdamp

### Structural representation

### Functional representation



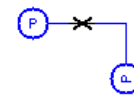
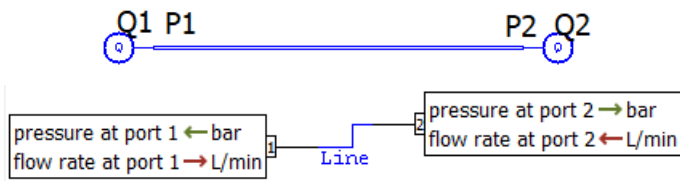
# EMR-based simulation using Simcenter Amesim

## - Simple hydraulic line and orifice-

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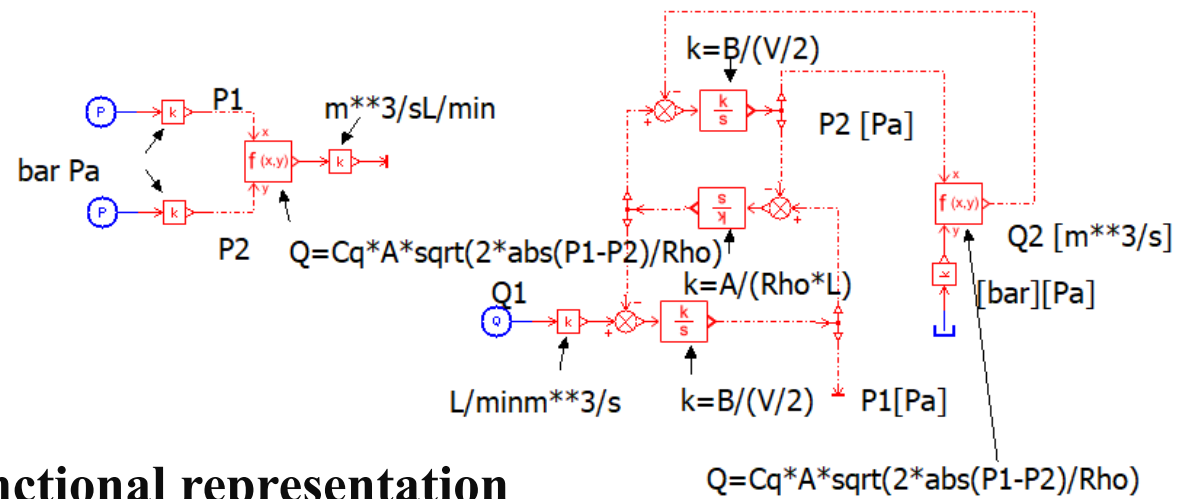
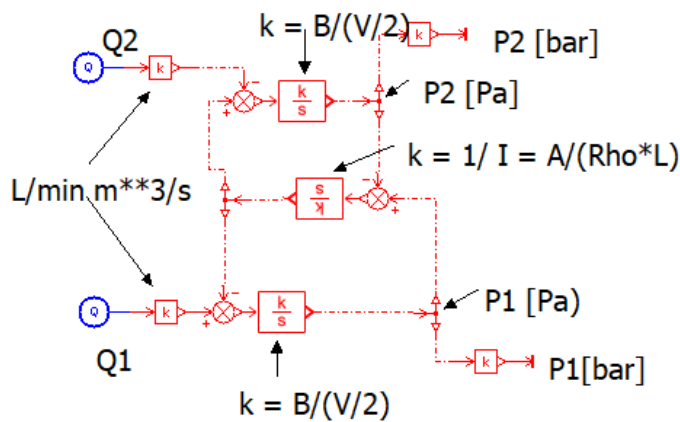
### Structural representation



**Model Line: C,I,C (Volume, Inertia, Volume)**

**Restriction**

**Circuit**



### Functional representation





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# «Panda EMR simulation»



# EMR-based simulation using Simcenter Amesim

## Vehicle EMR models

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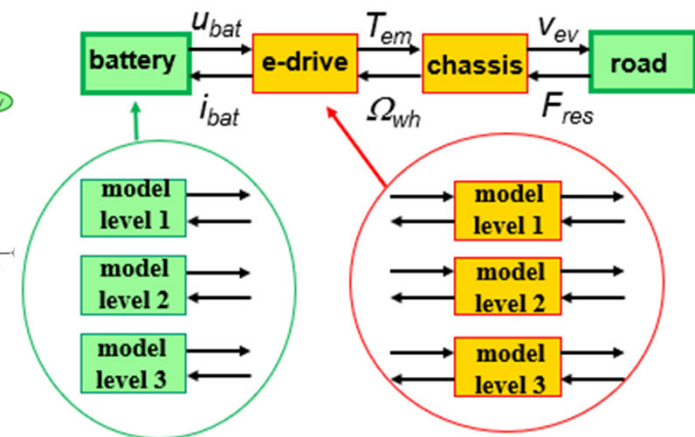
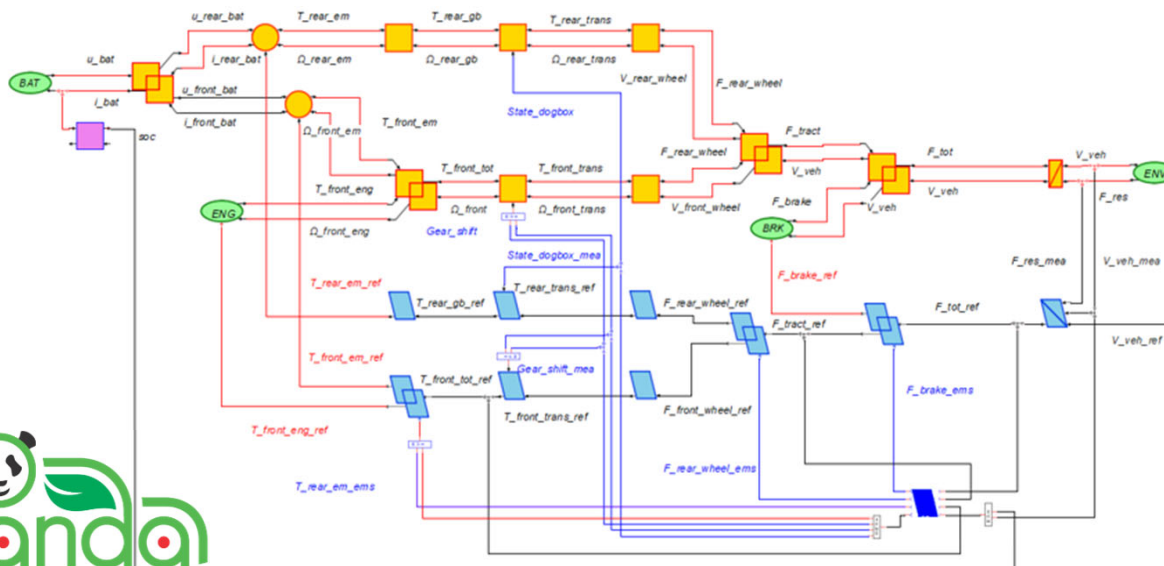
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PANDA Simcenter Amesim EMR n-level vehicle models based on:

Renault Zoe (BEV)

Mobypost (FCV)

Valeo Demo Car (P-HEV)

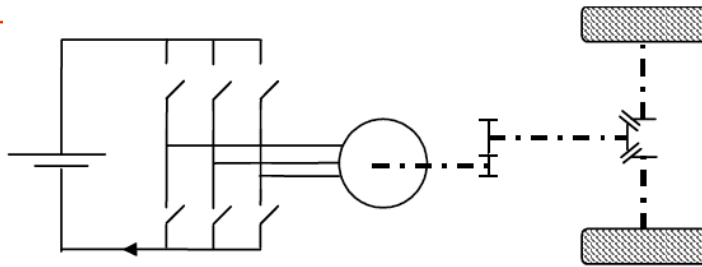


Powerful Advanced N-Level Digital Architecture  
for models of electrified vehicles and their components

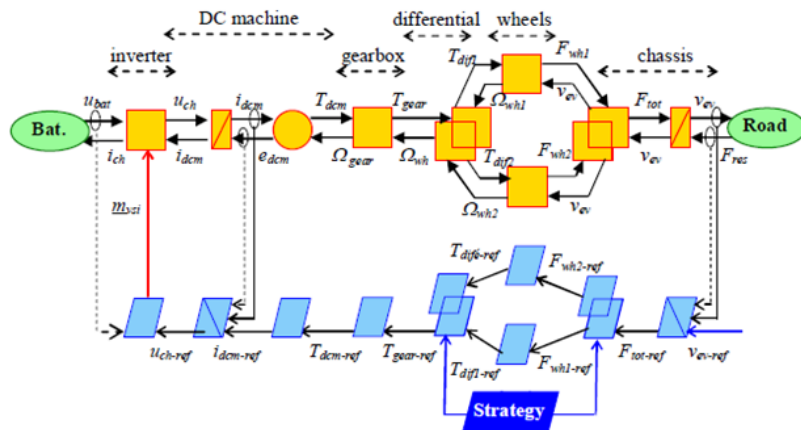
<https://project-panda.eu/virtual-testing/>

# EMR-based simulation using Simcenter Amesim

## EMR simulation model



- Battery - modelled by a simple source of D.C. voltage;
- PMSM - replaced by a DC machine;
- The Chopper - considered with a constant efficiency;
- Mechanical transmission - composed of a gearbox, a mechanical differential and one equivalent wheel;
- The chassis - represented with an equivalent mass.



Global Parameter Setup - EV\_19.ame

Right click to set global parameters: Search: [ ] [X] More >

Name	Title	Value	Unit
BATpV_batt	battery tension	400	V
EMpU_arm_nom	DC nominal tensi...	400	V
EMpI_arm_nom	DC nominal curr...	162	A
EMpN_nom	nominal speed	2840	rpm
EMpN_max	max speed	6000	rpm
EMpW_nom	nominal angular ...	3.14/30*EMpN_...	rad/sec
EMpP_nom	DC nominal power	65000	W
EMpDamp	viscous friction	0.1	Nm*sec/rad
EMpJ	equivalent inerti...	4.8	kg*m^2
EMpR_arm	DC resistance	0.35	Ohm
EMpL_arm	DC inductance	0.0065	H
EMpk_em	emf constant	(EMpU_arm_no...	V*sec/rad
EMpk_tq	torque constant	EMpK_em	Nm/A
EMpk_arm	Gain of the arma...	1/EMpR_arm	null
EMpT_arm	Time constant of...	EMpL_arm/EMpR...	null
CHp_eff	Chopper efficiency	0.95	null
MTpGear_eff	Gearbox efficiency	0.8	null
MTpk_gear	Gearbox ratio	5	null
MTpD_wheel	wheel diameter	0.52	m
MTpR_wheel	wheel radius	MTpD_wheel/2	m
MTpJ_wheel	wheel inertia	4.3	kg.m^2
CHApM_eq	Equivalent mass	1600	kg
CHApK_eq	Velocity gain	1/CHApM_eq	null
RDpwheelbase	wheelbase	2.4	m
RDpw_ev	EV width	1.6	m
RDpg	gravity	9.81	m/s^2
RDpA	frontal area	2	m^2
RDpCx	Drag coefficient	0.35	null
RDpro	Density of the air	1.223	kg/m^3

Help OK Cancel Apply

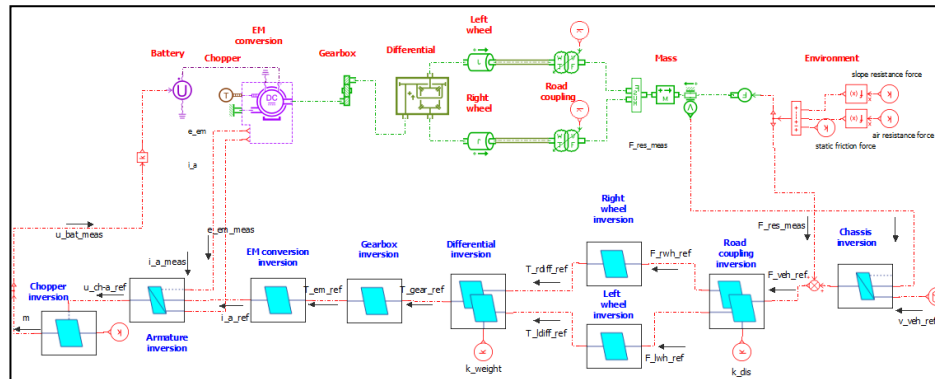
# EMR-based simulation using Simcenter Amesim

## - Results using a functional library -

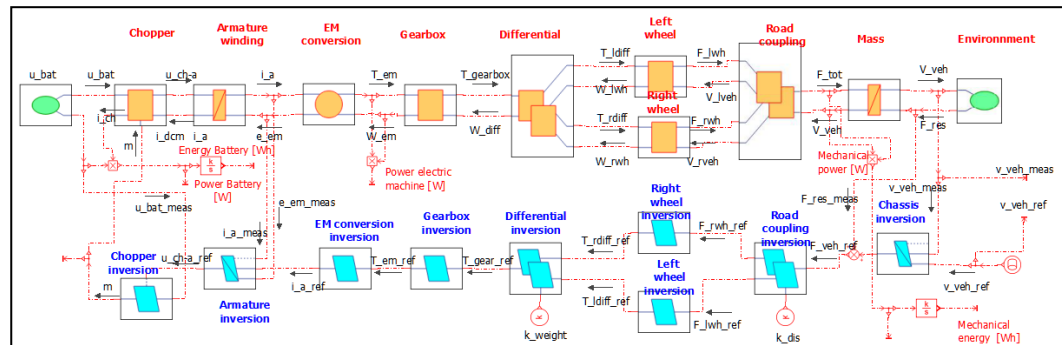
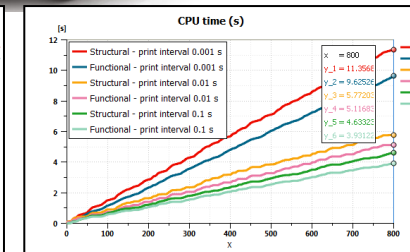
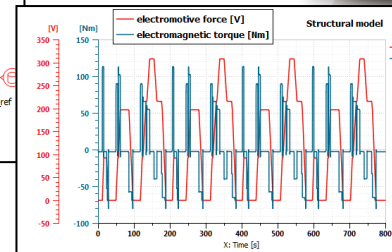
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### Classical Simcenter Amesim structural library



### Simulation of Renault ZOE



- same model / control
- same accuracy
- -15% of computation time with the functional library

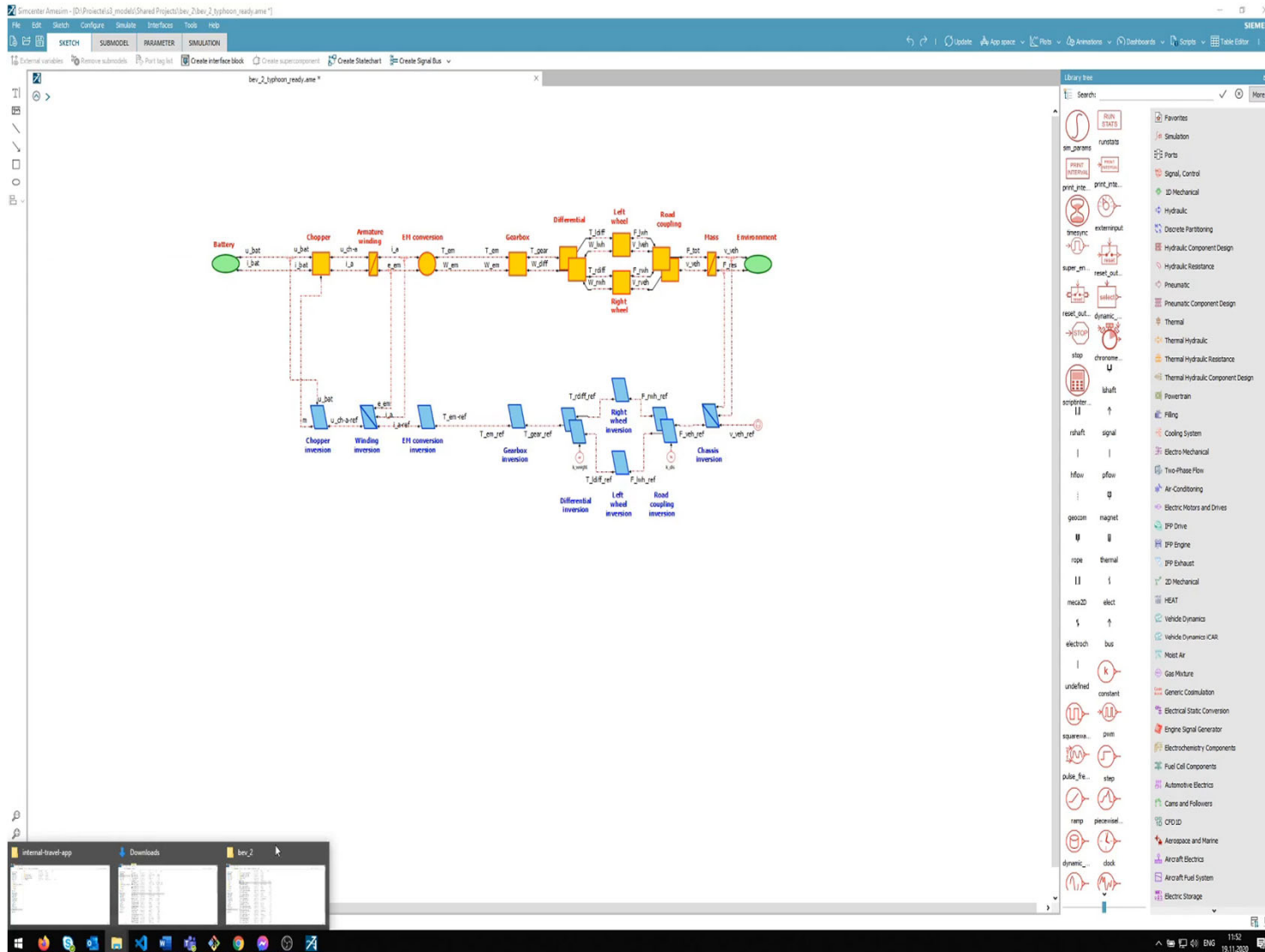
### New EMR-based (functional) library in Simcenter Amesim

# EMR-based simulation using Simcenter Amesim

## - From Simulation to Test -

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# « BIOGRAPHIES AND REFERENCES »

# EMR-based simulation using Simcenter Amesim

- Authors -

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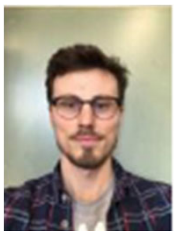


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**Florian TOURNEZ** PhD student & Research engineer  
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de Lille**

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



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[Husar 2019] C. Husar, M. Grovu, C. Irimia, A. Desreveaux, A. Bouscayrol, M. Ponchant, P. Magnin, "Comparison of Energetic Macroscopic Representation and structural representation on EV simulation under Simcenter Amesim", IEEE-VPPC'19, Hanoi (Vietnam), October 2019 (Siemens Software and L2EP within the framework of the H2020 PANDA project)

[PANDA 2019] A. Bouscayrol, A. Lepoutre, C. Irimia, C. Husar, J. Jaguemont, A. Lièvre, C. Martis, D. Zuber, V. Blandow, F. Gao, W. Van Dorp, G. Sirbu, J. Lecoutere, "Power Advanced N-level Digital Architecture for models of electrified vehicles and their components", Transport Research Arena 2020, Helsinki (Finland), April 2020 (within the framework of the PANDA H2020 European Project, GA #824256).

<https://project-panda.eu/>

<https://project-panda.eu/virtual-testing/>

[Simcenter Amesim] <https://plm.sw.siemens.com/en-US/simcenter/systems-simulation/amesim/>