SIEMENS
Ingenuity for life

Comparative study between a homogeneous and a heterogeneous approach for modeling an electric powertrain in Simcenter Amesim

Agenda

- Simcenter Amesim overview
- Electrical vehicle model description
- Modelica inverter model
- Comparison between homogeneous and heterogeneous approach
- Conclusions

Agenda

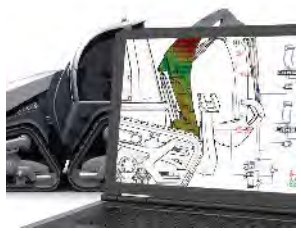
- **Simcenter Amesim overview**
- **Electrical vehicle model description**
- **Modelica inverter model**
- **Comparison between homogeneous and hybrid model**
- **Conclusions**

Simcenter system simulation solutions

SIEMENS
Ingenuity for life

Industry Sector

- Automotive & Transportation
- Aerospace & Defense
- Heavy Equipment
- Industrial Machinery
- Marine
- Energy & Utilities

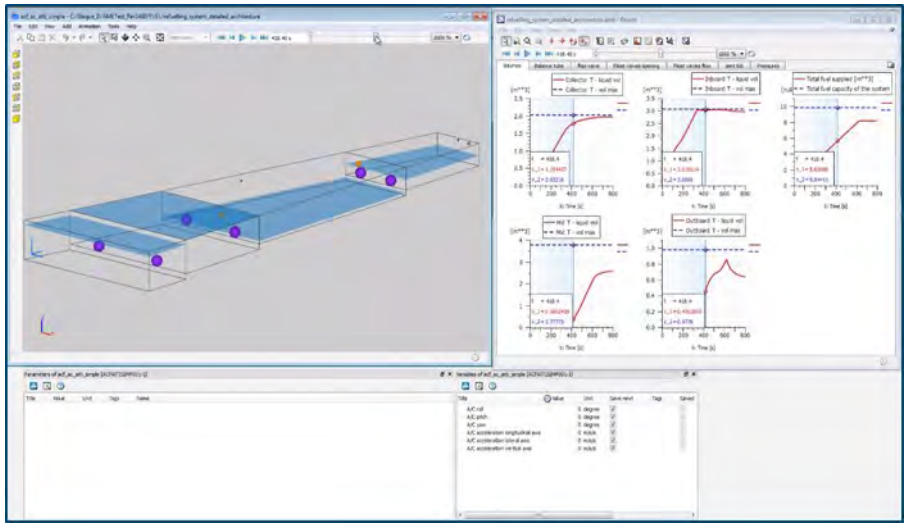


Pre-design

Performance analysis

Design Optimization

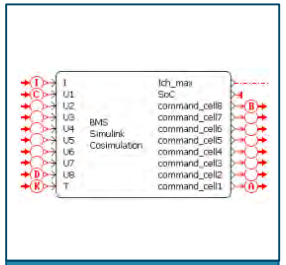
Controls validation



Scalable simulation

Connecting “mechanical” – “controls”

Multi-physics

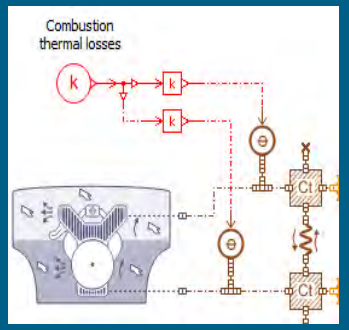


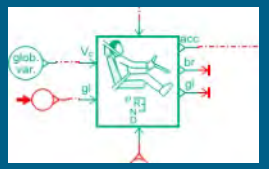
Co-simulation

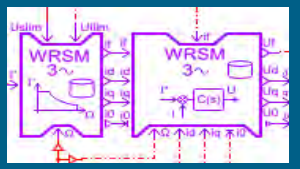
Open and customizable

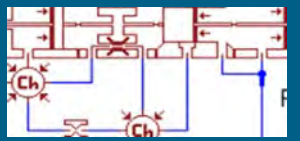
>40 libraries

>5,000 models









Mechanical

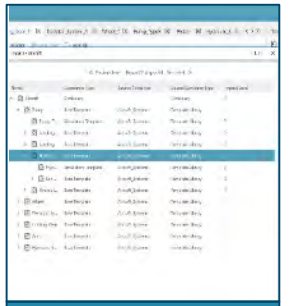
Hydraulics/Pneumatics

Thermal

Electrical

Magnetic

Chemical



Model Architecture

Open platform

SIEMENS
Ingenuity for life

Platform facilities:
Data management, pack, libraries, supercomponents…

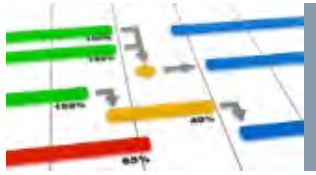
Solvers and numerics:
Solver technology, Parallel computing, HPC, ..

Analysis tools:
Eigenvalues, Modal shapes, Bode plots, …

MIL/SIL/HIL and real-time:
Blackbox, RT FMUs,
Precompiled objects for RT targets…

Optimization, robustness, design of experiments:
NLPQL, Parameter sweep, Monte Carlo, Genetic Algorithms

Software interfaces:
FMI export/import 1.0-2.0
dedicated interfaces (Simulink,etc…), Excel import, in-house codes…



Simulator scripting & APIs:
C/C++, python, VBA, matlab, scilab, console…

1D/3D CAE:
CAD import, FE import, CFD coupling,…

Customization:
App designer, customized components…

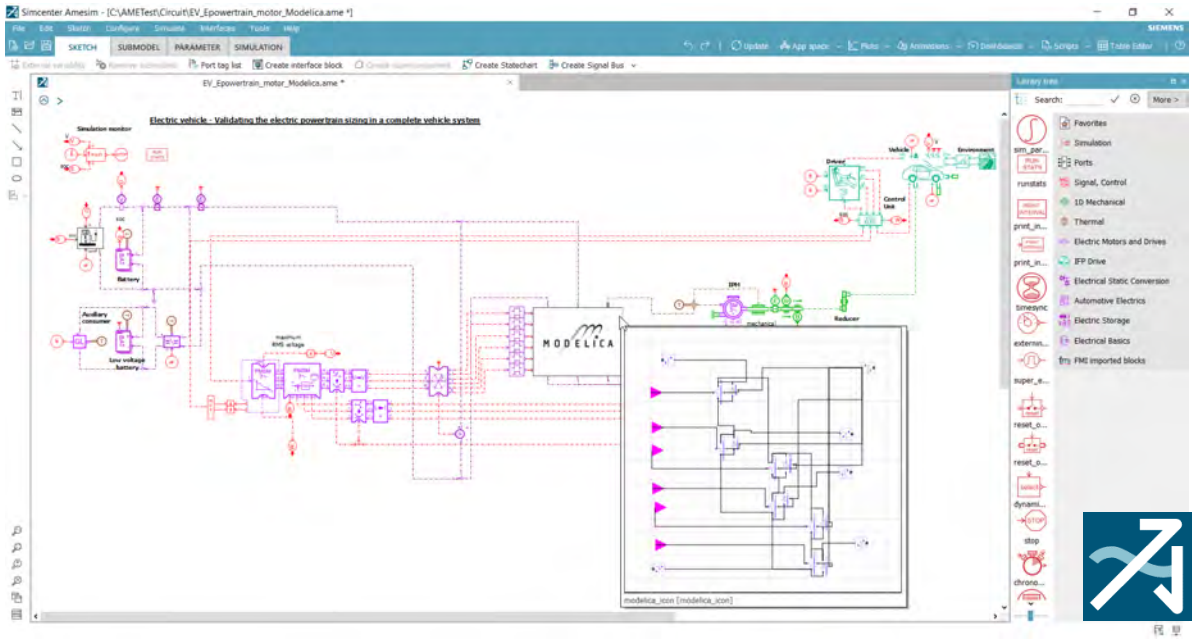
Modelica

Modelica platform

Simcenter Amesim & Modelica

SIEMENS
Ingenuity for life

Modeling & Simulation platform | **Modelica engine** | **Modelica edition**



Simcenter Amesim platform

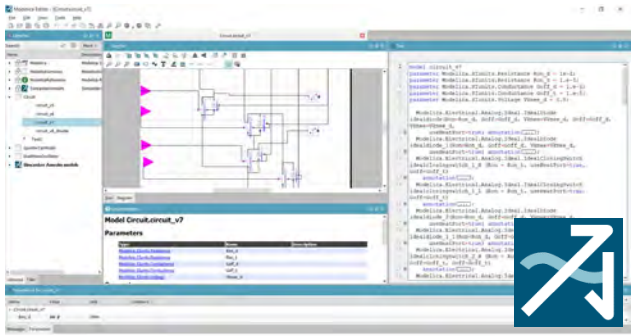
Embedded in Amesim

FMI 2.1

OPTIMICA Compiler Toolkit

by Modelon

Modelica file

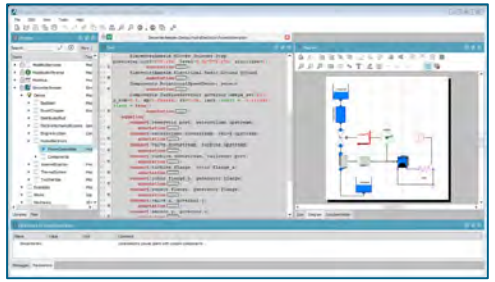


Modelica Editor

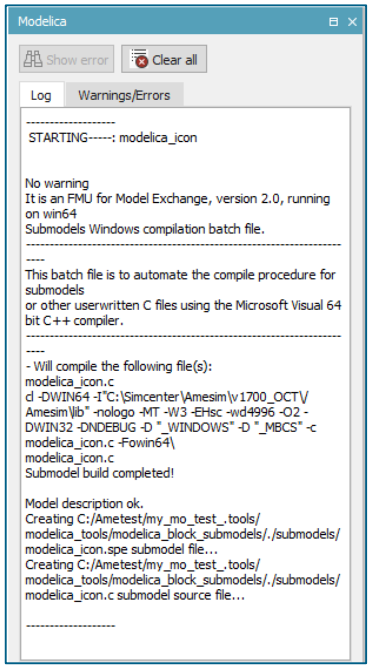
Basic workflow

SIEMENS
Ingenuity for life

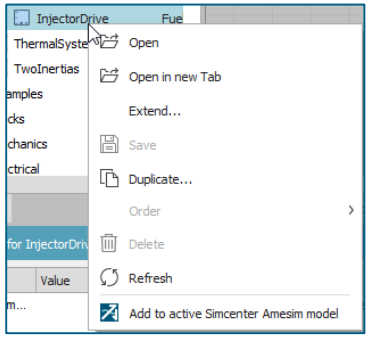
Create → Compile → Connect → Simulate → Analyze

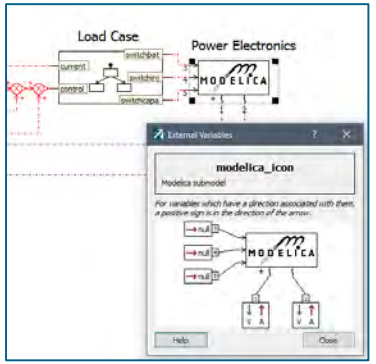


- Full-featured, configurable IDE
- Source code editor
- Graphical component assembly
- MSL v3.2.2
- Easy library loading

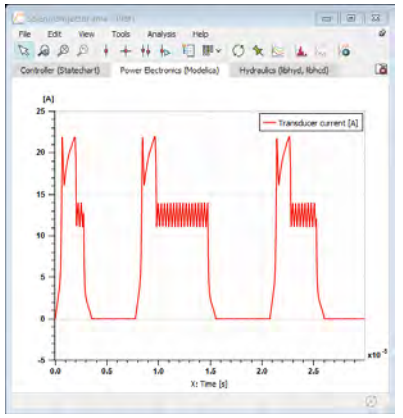


Automated compiling when model added to Simcenter Amesim

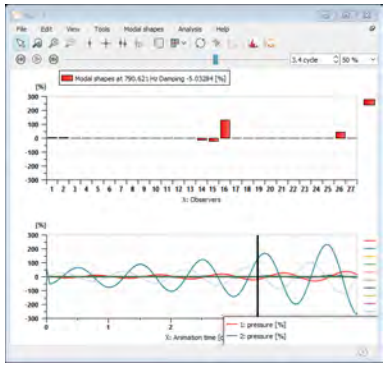




Connection with native libraries through dedicated physical connectors – FMI 2.1



Solved as whole system, **in Model Exchange**. Compatible with Simcenter Amesim **simulation** capabilities: Batch/Design Exploration, HPC, MIL/SIL/HIL…



Compatible with Simcenter Amesim platform capabilities: Performance analyzer, linear **analysis** (eigenvalues, modal shapes, frequency response, root locus…), dashboards, scripting,…

Agenda

- Simcenter Amesim overview
- **Electrical vehicle model description**
- Modelica inverter model
- Comparison between homogeneous and hybrid model
- Conclusions

Model definition of a complete electrical vehicle system used for the sizing of the electric powertrain

SIEMENS
Ingenuity for life

- EV Model Based Design
- Supporting BEV design project to define requirements for instance
- Focus on the electrical system
- Electrical motor control system validation
- Simulation of high frequency effects on the electrical system

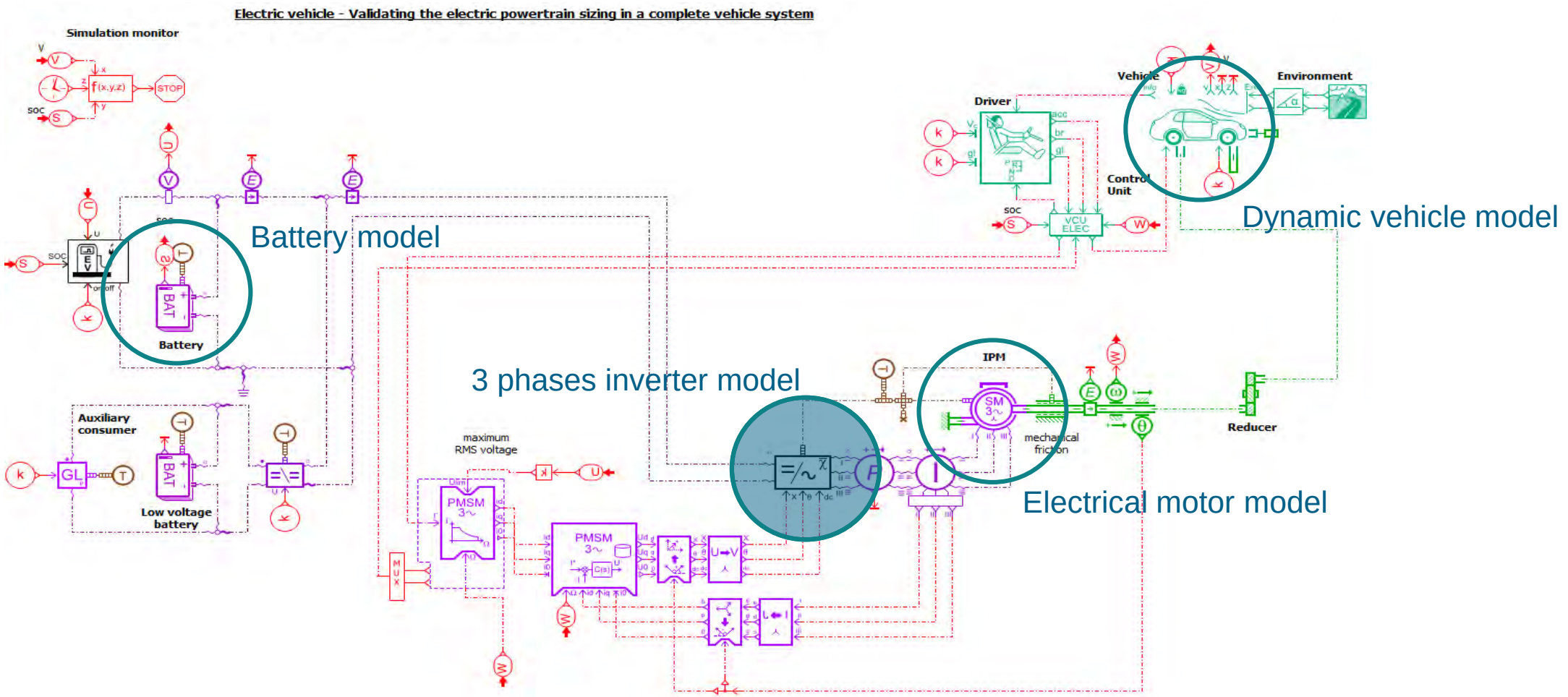
Multi-level modeling

SIEMENS
Ingenuity for life

EV model	Electric motor	Inverter	Battery	Gearbox	Chassis	Range and Perfo
Level 1	Static	Balanced	Generic battery	Ratios efficiency	One inertia	
Level 2	Quasi-static	Average	Advanced model (semi-empiric)	Flywheel inertia	3 DoF (2D)	
Level 3	Dynamic	Switched	Advanced model (semi-empiric) + thermal	Detailed rotary stiffness and inertia	18 DoF (3D)	
Level 4	Cooperation with FEM		Advanced model (semi-empiric) + aging			

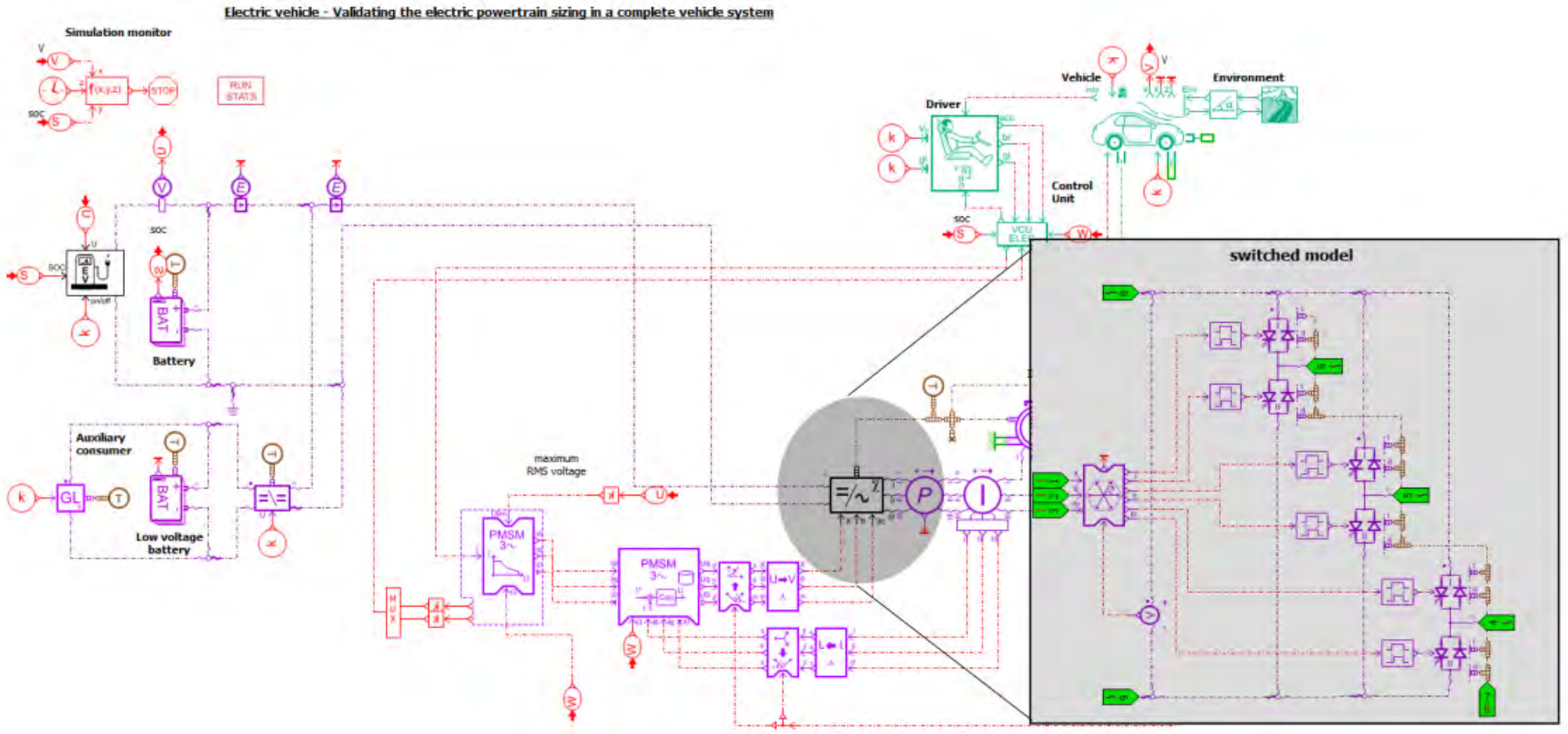
Simcenter Amesim electrical vehicle model

SIEMENS
Ingenuity for life



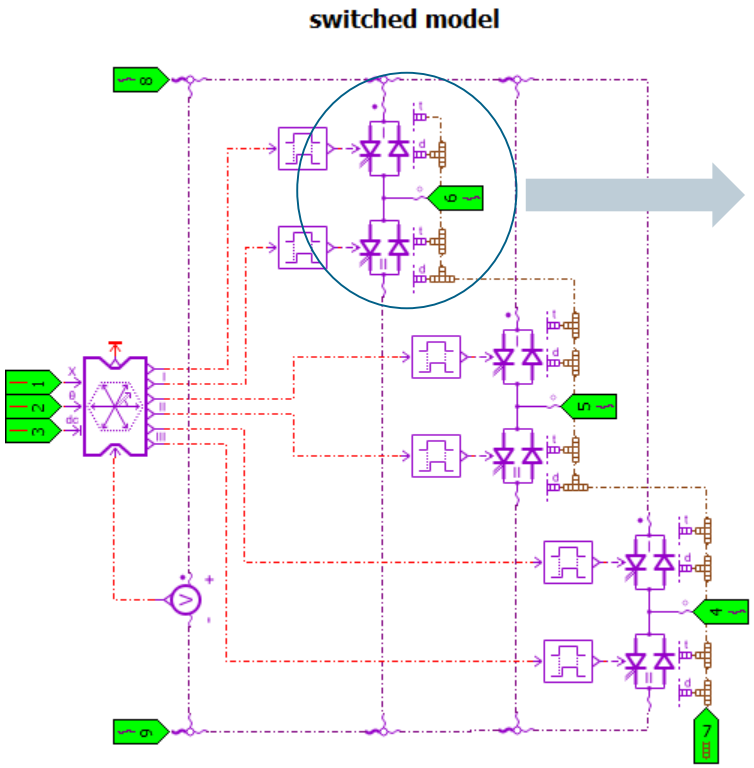
Inverter component characterization

SIEMENS
Ingenuity for life

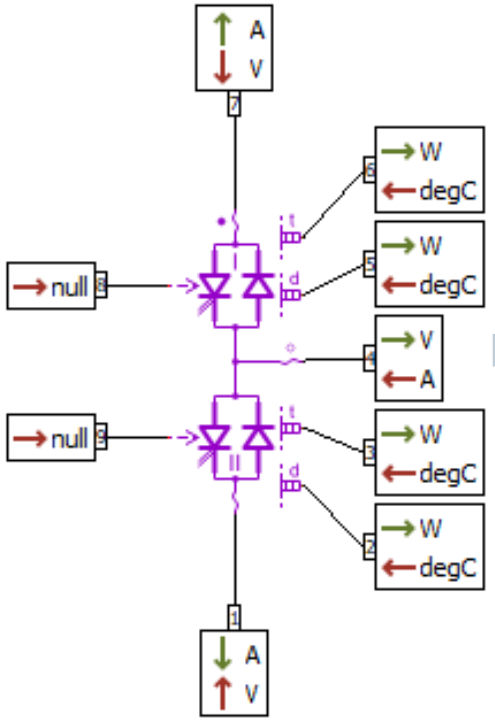


Inverter component characterization

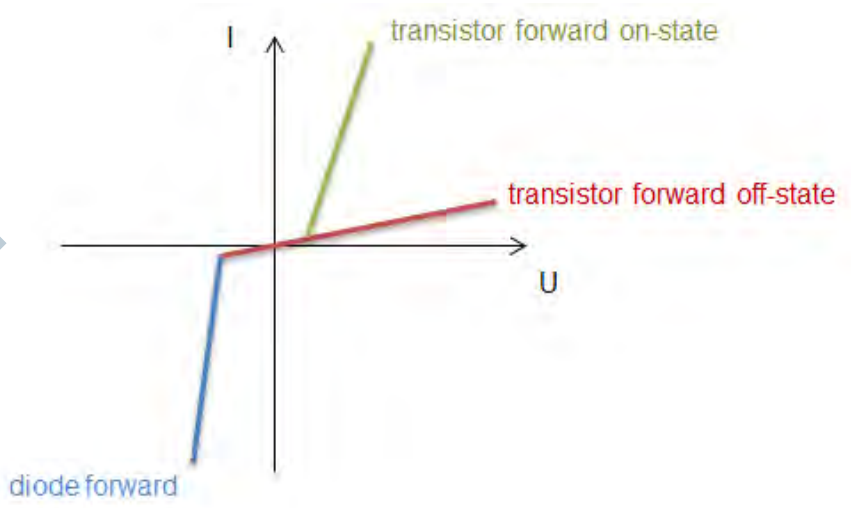
3 switched inverter arms
➔Conduction
➔Switching losses quasi-static way



2 modules composed by a transistor and an antiparallel diode



Electro/thermal coupling

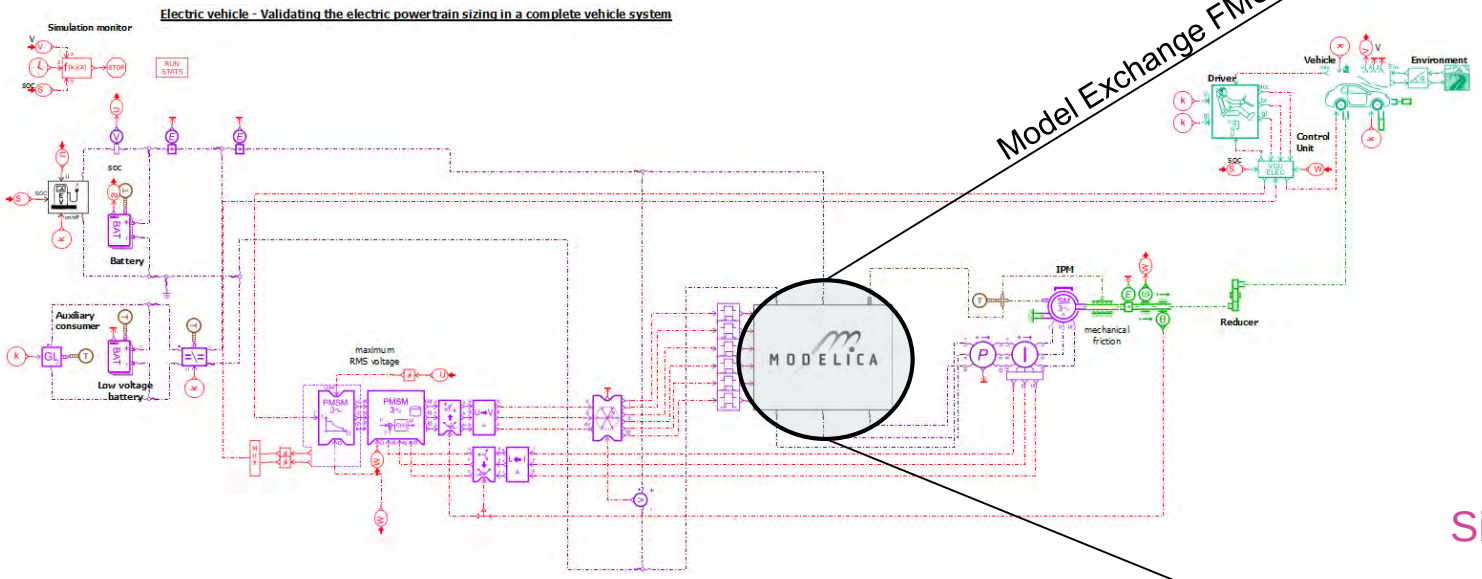


Agenda

- Simcenter Amesim overview
- Electrical vehicle model description
- **Modelica inverter model**
- Comparison between homogeneous and hybrid model
- Conclusions

Inverter Component Modelica based

SIEMENS
Ingenuity for life



Simcenter Amesim sketch

Model Exchange FMU 2.1

Electrical port

Thermal port

3 Arms

Signal ports

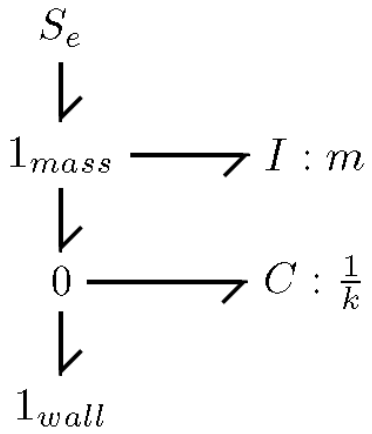
MSL 3.2.2

Modelica Editor Diagram

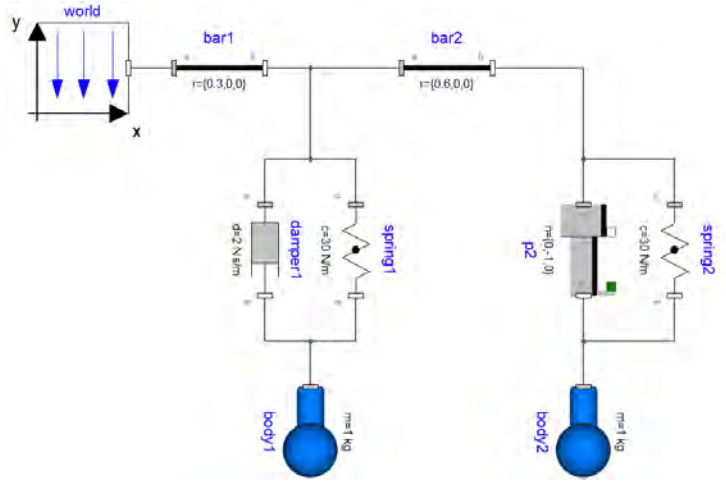
Agenda

- Simcenter Amesim overview
- Electrical vehicle model description
- Modelica inverter model
- **Comparison between homogeneous and hybrid model**
- Conclusions

Modeling approaches: Simcenter Amesim / Modelica



Bond graph representation
For causal models

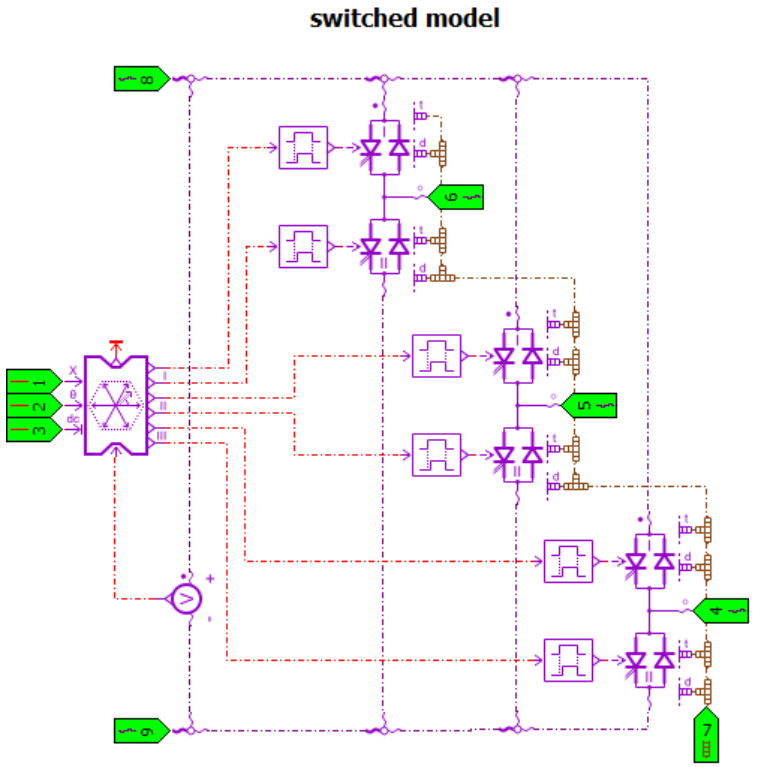


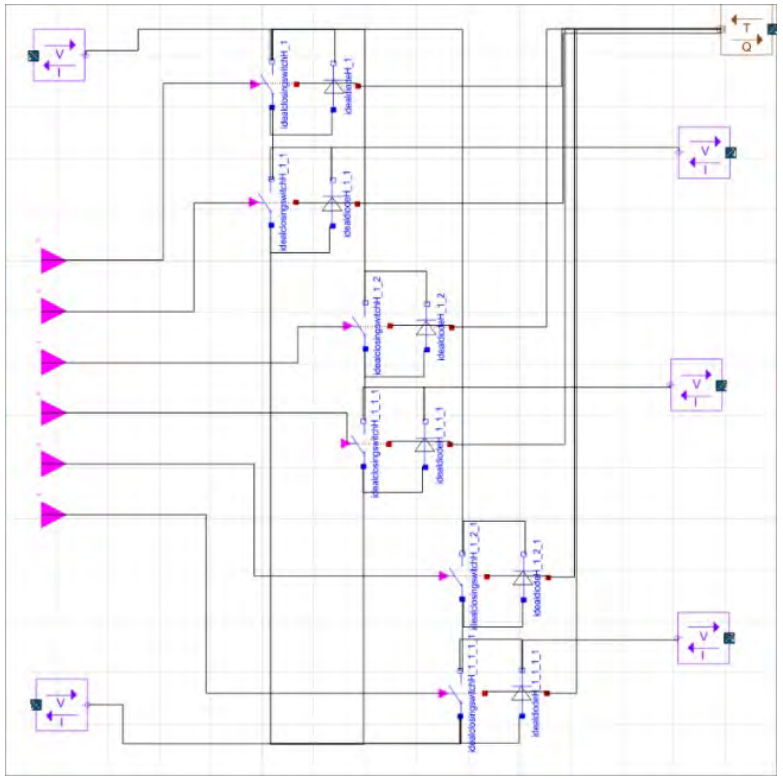
Kirchhoff's laws representation
For acausal models

Simcenter Amesim combines this approach and a representation of the components grouped into specialized libraries

Declarative model, without preferred causality. Enabling the direct manipulation of a set of algebraic differential equations

In practice





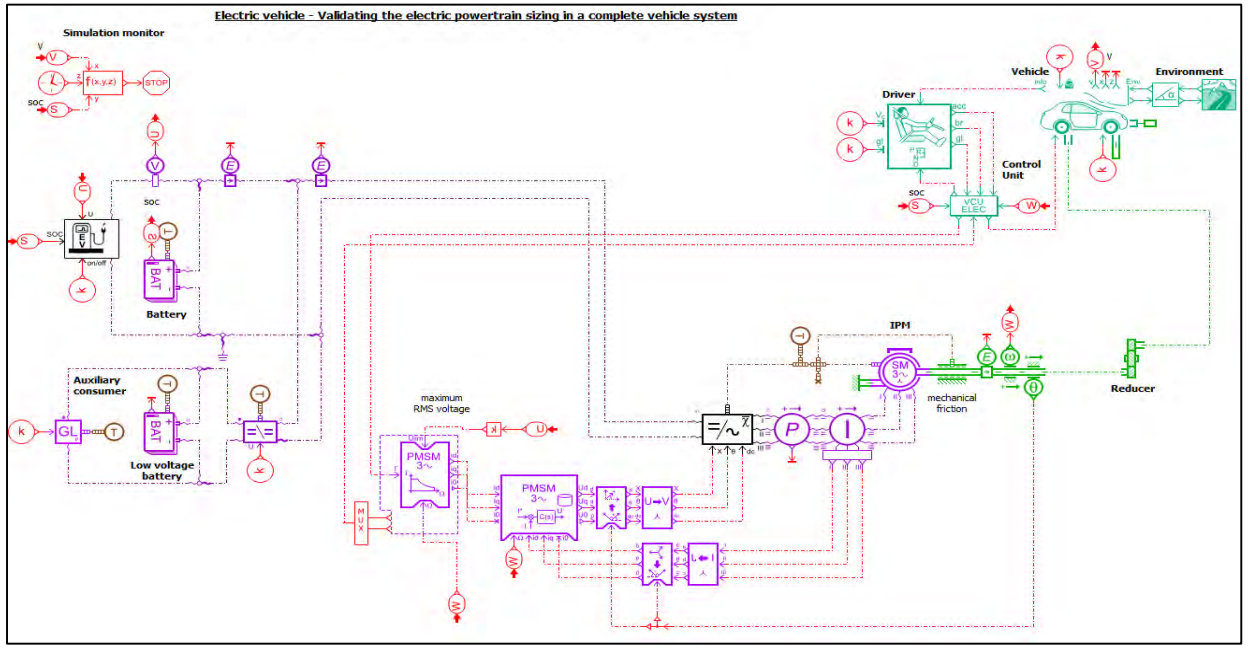
Specific study and development to have an arm composed by 2 modules

Simple step by step composition based on connection of single systems find in the MSL

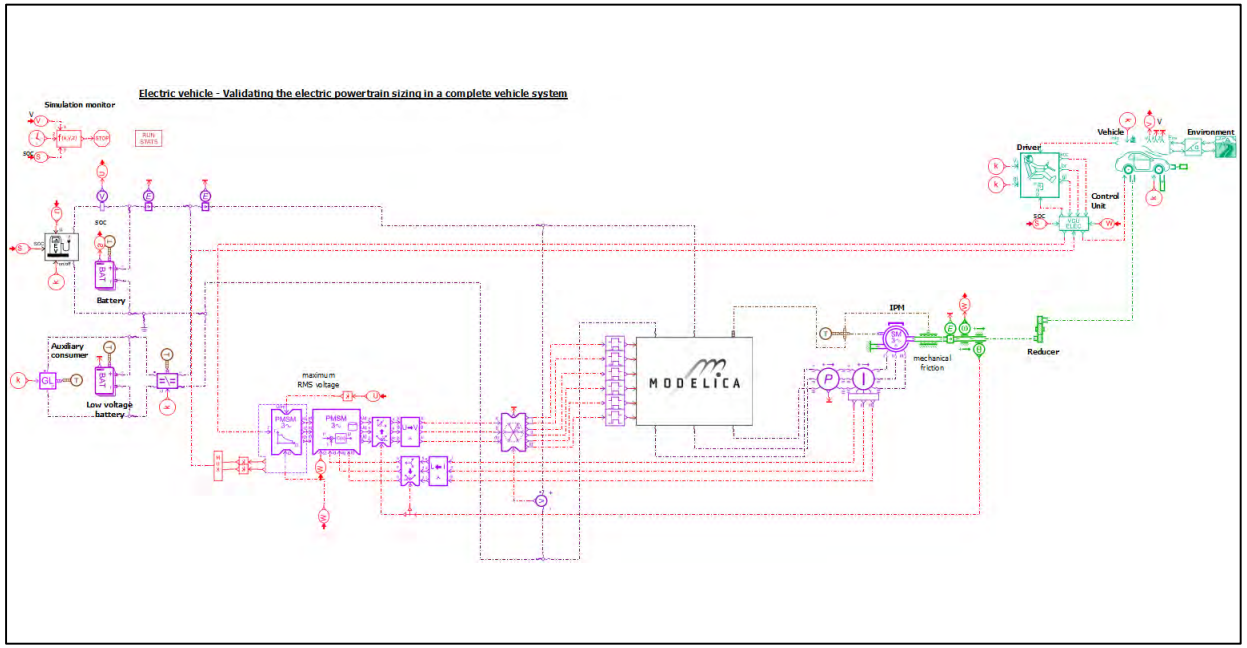
Settings

SIEMENS
Ingenuity for life

Homogeneous model

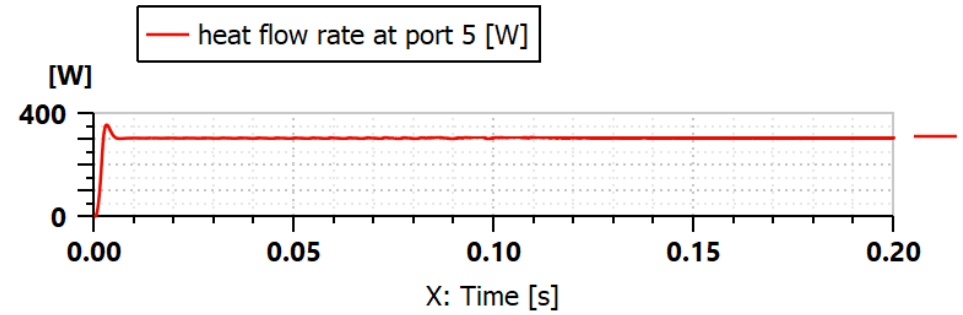


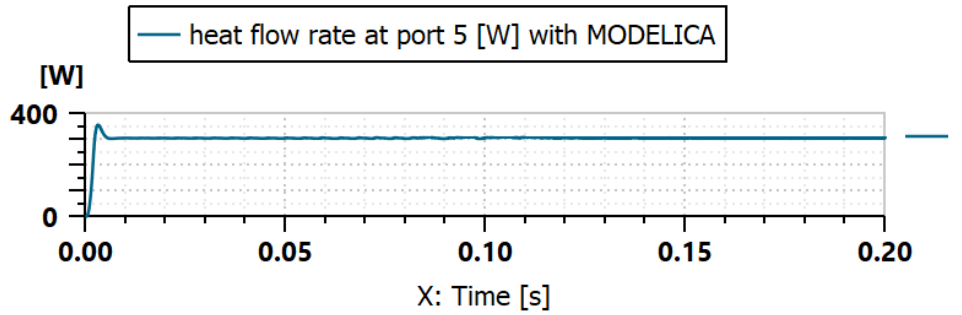
Heterogeneous model

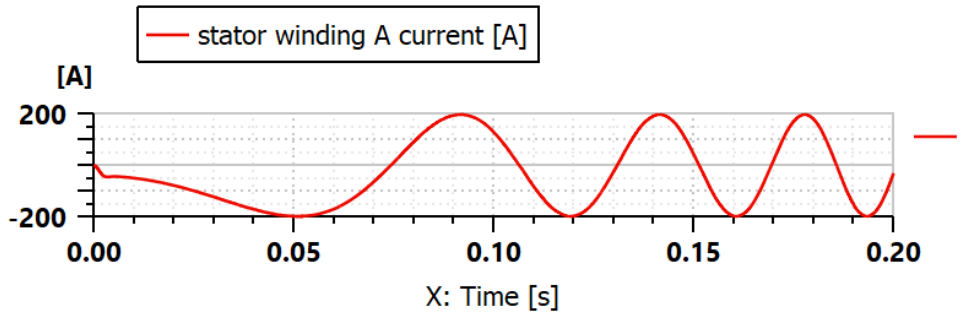


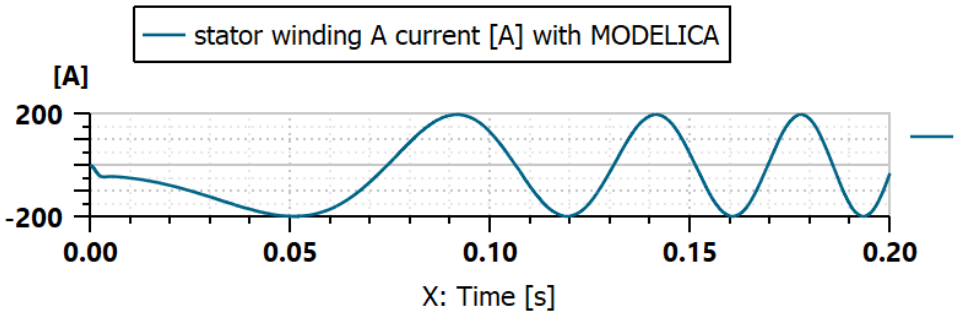
diode forward resistance	**0.00234**	Ohm
diode forward threshold voltage	**0.9**	V
transistor on-state resistance	**0.00262**	Ohm
transistor forward threshold voltage	**0**	V
diode turn-off switching energy at reference voltage and current	0	J
diode turn-on switching energy at reference voltage and current	0	J
transistor turn-on switching energy at reference voltage and current	**0**	J
transistor turn-off switching energy at reference voltage and current	**0**	J
idealdiode_2_1.Goff - Backward state-off conductance (opened conductance)	**1/(Roff/2)**	S
off-state resistance	**1000000**	Ohm

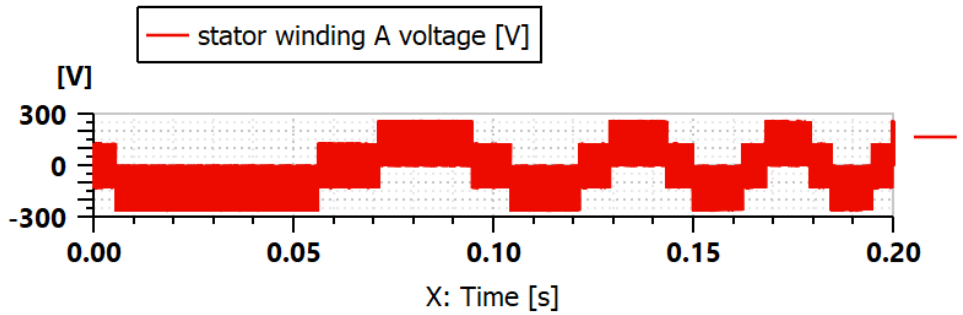
Inverter results for a 0.2 second simulation
Same print interval, same solver

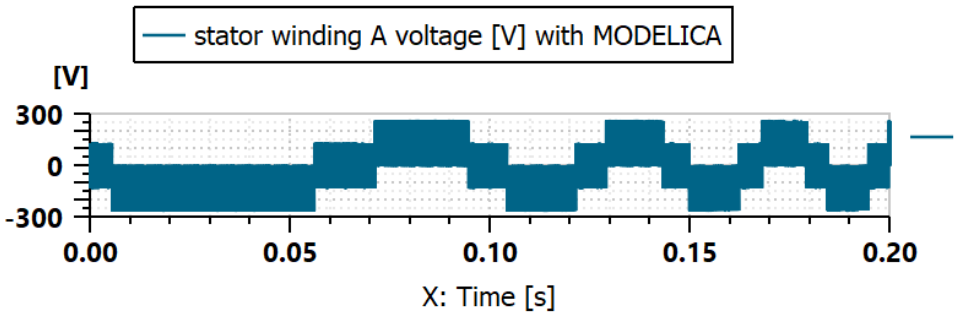






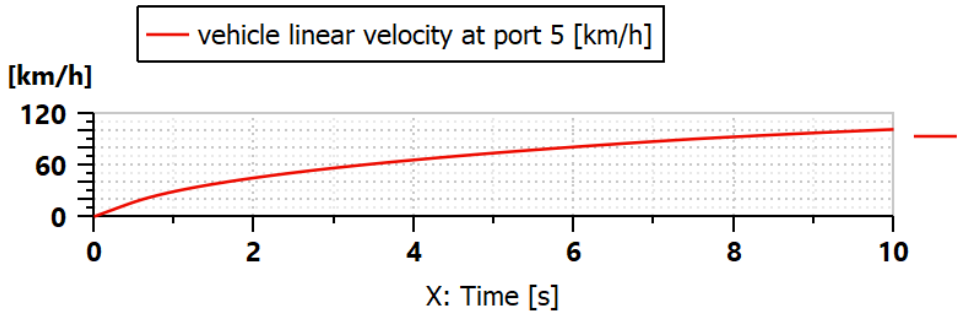


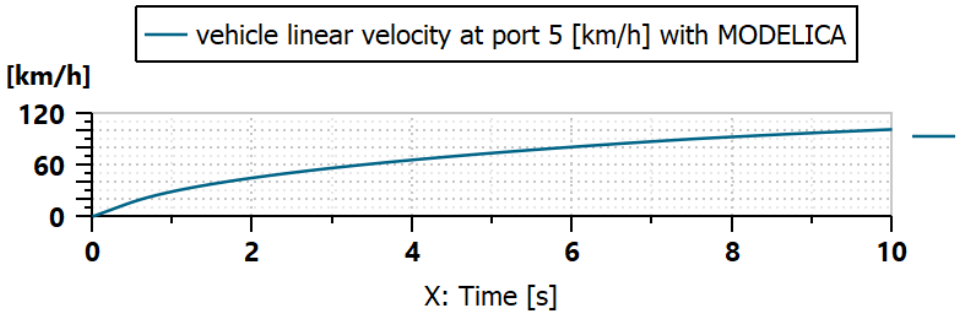


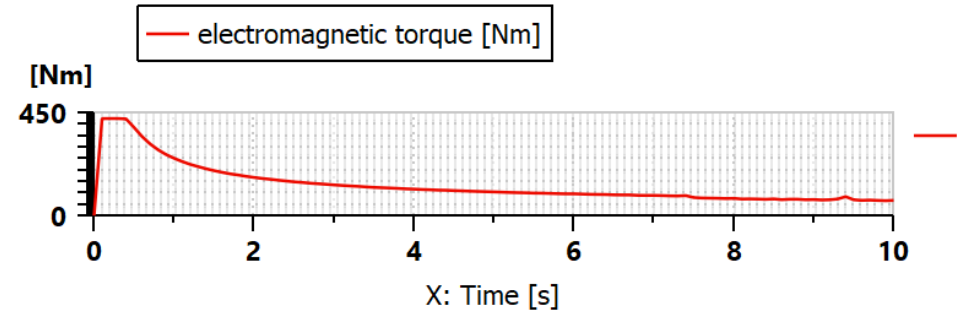


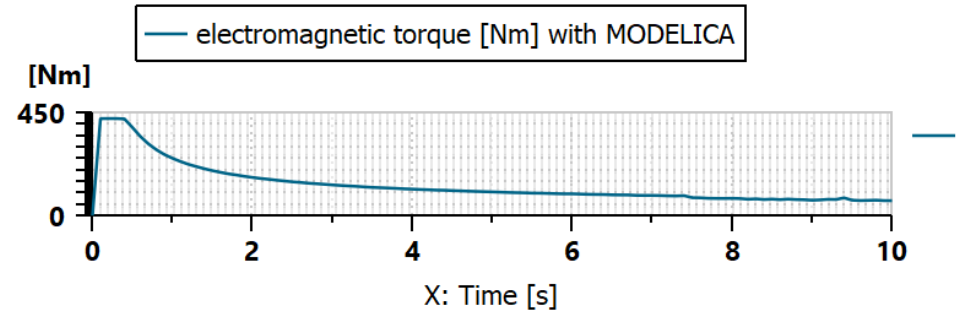
Global results for a 10 seconds simulation
Same print interval, same solver

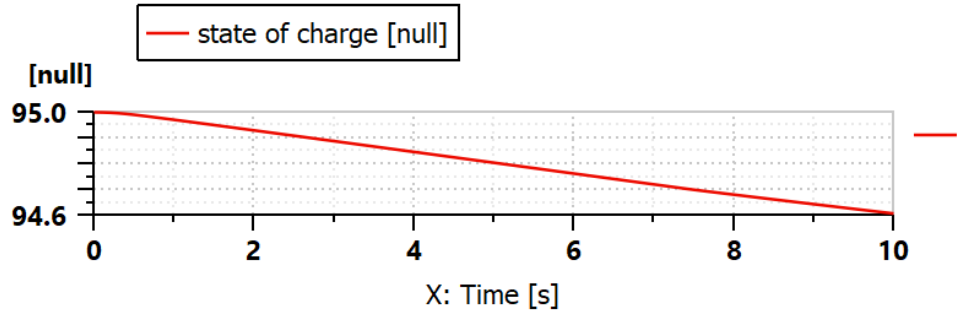
SIEMENS
Ingenuity for life

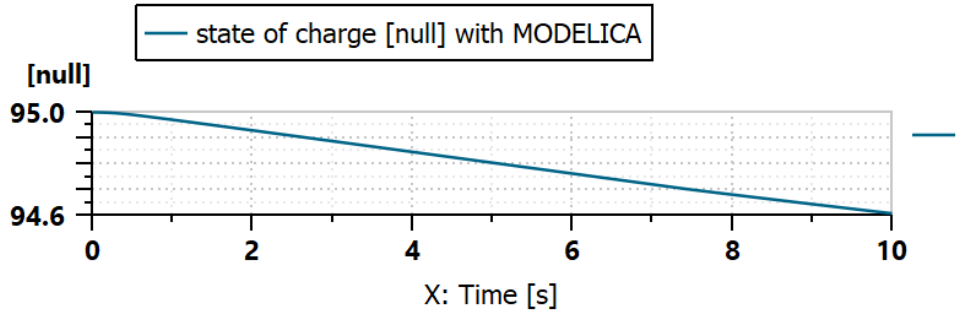




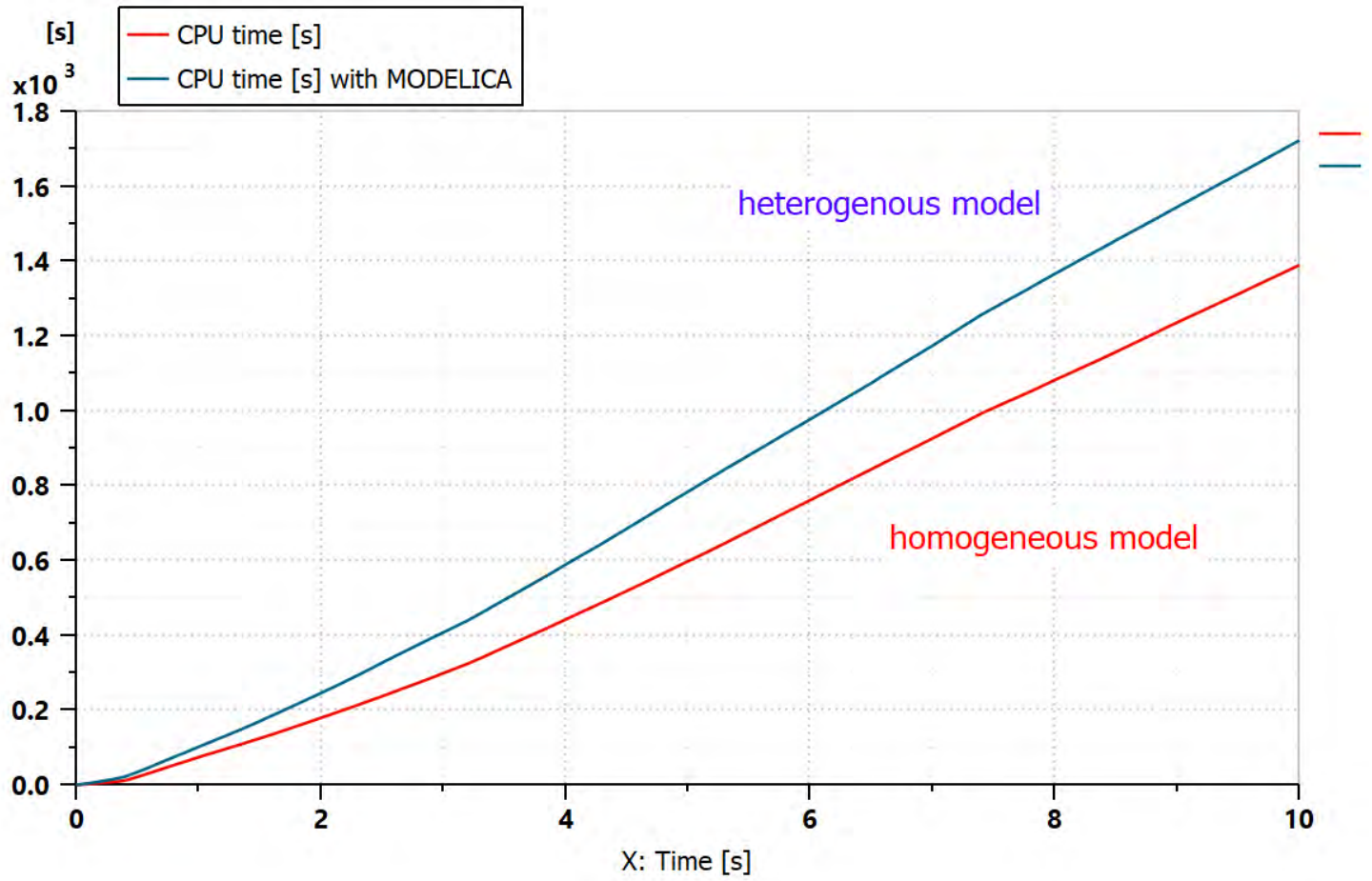








CPU time comparison



- Performance drop of 20% by using the heterogeneous approach
- May be linked to the Modelica approach due to a none optimal symbolic processing for this use case

Agenda

- Context
- Electrical vehicle in Simcenter Amesim
- Modelica inverter
- **Conclusions**

Conclusions

SIEMENS
Ingenuity for life

- Simcenter Amesim platform can perform hybrid modeling mixing causal and acausal approach
- The hybrid model of the Electrical Vehicle can be used for validating the electric powertrain sizing
- During the modelling phase the Modelica approach can be complimentary and facilitate locally the development of sub-models
- For instance, if we want to create an inverter with more than 2 modules in parallel to increase the current, clearly the Modelica approach should be recommended
- A slight disadvantage during the simulation for the hybrid model, the simulation performances decreased by 20% for 10 seconds of simulation

Karim Besbes

Siemens DI Software / Simulation & Test Solutions Department

karim.besbes@siemens.com

Where today meets tomorrow.

14th MODPROD Conference 2020, Linköping, Sweden