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

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

Open and customizable

Co-simulation

Model Architecture

>40 libraries

>5,000 models

Mechanical
- Hydraulics/Pneumatics
- Thermal
- Electrical
- Magnetic
- Chemical

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Page 4

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Open platform

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

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

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

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

Customization:
App designer, customized components…

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

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

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

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

Modelica platform
Simcenter Amesim & Modelica

Modeling & Simulation platform

Modelica engine

Modelica edition

Simcenter Amesim
platform

OPTIMICA
Compiler Toolkit

by Modelon

Modelica Editor

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Basic workflow

Create

• 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

Compile

Simulate

Automated compiling when model added to Simcenter Amesim

Connection with native libraries through dedicated physical connectors – FMI 2.1

Analyze

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

- 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

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric motor</td>
<td>Inverter</td>
<td>Battery</td>
<td>Gearbox</td>
</tr>
<tr>
<td>Static</td>
<td>Balanced</td>
<td>Generic battery</td>
<td>Ratios efficiency</td>
</tr>
<tr>
<td>Quasi-static</td>
<td>Average</td>
<td>Advanced model (semi-empiric)</td>
<td>Flywheel inertia</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Switched</td>
<td>Advanced model (semi-empiric) + thermal</td>
<td>Detailed rotary stiffness and inertia</td>
</tr>
<tr>
<td>Cooperation with FEM</td>
<td></td>
<td>Advanced model (semi-empiric) + aging</td>
<td></td>
</tr>
</tbody>
</table>

Range and Perfo

Accuracy
Required data
CPU consumption
Simcenter Amesim electrical vehicle model

Battery model

Dynamic vehicle model

3 phases inverter model

Electrical motor model
Inverter component characterization
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
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Inverter Component Modelica based

Simcenter Amesim sketch

Modelica Editor Diagram

Electrical port

Thermal port

3 Arms

Signal ports

MSL 3.2.2
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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**

### Homogeneous model

#### Electric vehicle - Voltability and electric powertrains sizing in a complete vehicle system

- **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-off switching energy at reference voltage and current**: 0 J
- **Transistor turn-on switching energy at reference voltage and current**: 0 J
- **ideal_diodo_2_1_Goff - Backward state-off conductance (open state conductance)**: \(1/(\text{Goff}/2)\) S
- **off-state resistance**: 1000000 Ohm

### Heterogeneous model

#### Electric vehicle - Voltability and electric powertrains sizing in a complete vehicle system

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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

- Vehicle linear velocity at port 5 [km/h]
  - without MODELICA
  - with MODELICA

- Electromagnetic torque [Nm]
  - without MODELICA
  - with MODELICA

- State of charge [null]
  - without MODELICA
  - with MODELICA
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

- 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