Scalability in Chassis Subsystem Modeling – From Simple to Complex Models and Model Simplification for Real-Time

Vehicle Dynamics Expo – 2010 June 23rd

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Agenda

Model Simplification – Problem Positioning

- The user of any simulation tool should answer to the question "**How complex should the model be**?" and this **not only for real time purpose**.
- A simple answer to this question comes from Einstein words "**As complex as necessary**". However achieving this task is not so simple …
- A definition of an efficient model (generally called a **proper model**) can be **a model having enough details to model the objectives with the simplest possible layout**.
- General targets of a proper model are to have:
  - First **physically meaningful parameters and state variables**
  - Second the **minimum complexity required to address the modeling objectives** (frequency range of interest and CPU load in case of real time)
- Concerning the second point, some tools/techniques/rules/models have to be found in order to **step by step simplify** a complex and validated model. These simplifications are generally difficult to be done automatically and often required **engineering judgment**.

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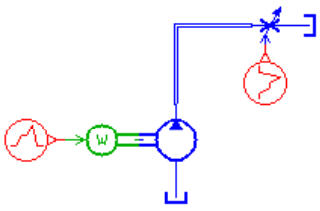
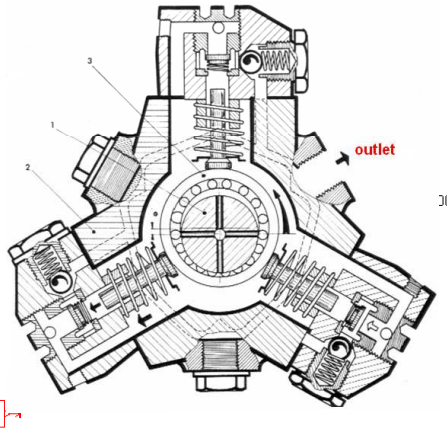
Model Simplification – Problem Positioning

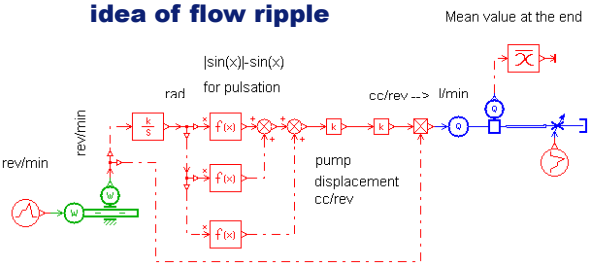
If I would like to model a pump, I can obtain these models:

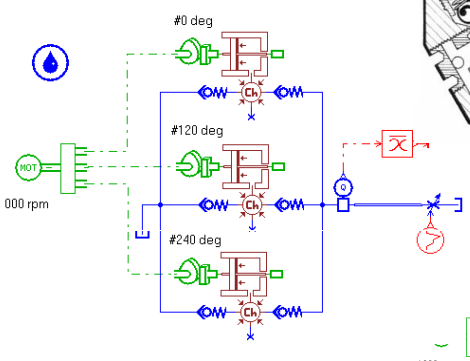


Only displacement

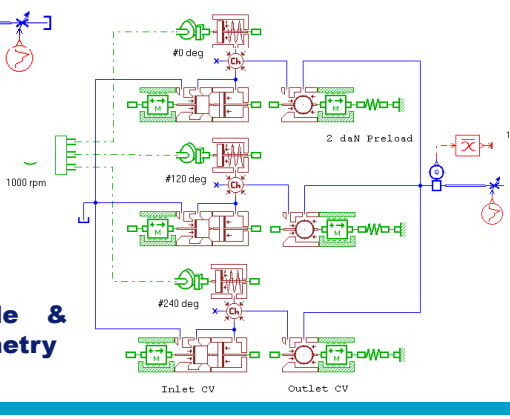


Kinematic & first idea of flow ripple

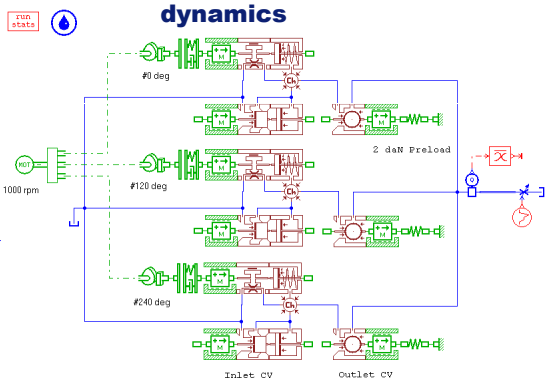




Flow ripple & first dynamics



Flow ripple, valve & piston dynamics



Flow ripple & valve geometry

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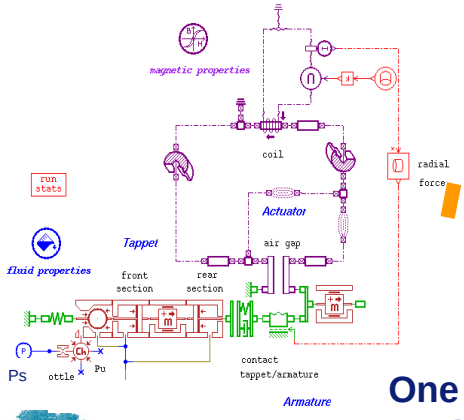
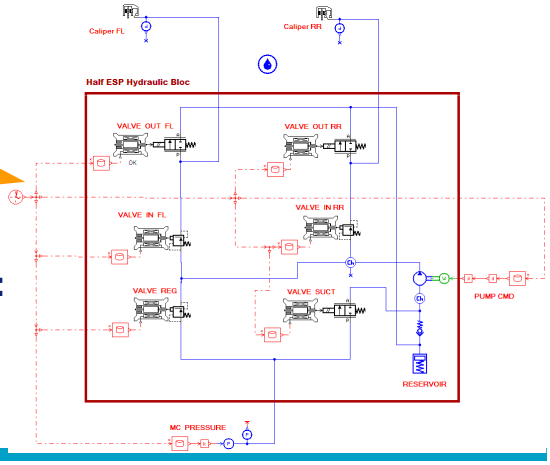
Model Simplification – Problem Positioning

- Going from simple to more complexity requires more Physics/more details inside the modeling approach (**which physical phenomena for which contribution**).
- However, here, the objective is to **have a validated complex model** and, from this model **to obtain a much simpler model**.
- The purpose of this can be for batch or optimization or simply to reduce the CPU time (not only for real time).
- How can I reduce a complex validated model?



One of the CHALLENGES: Model simplification



Agenda

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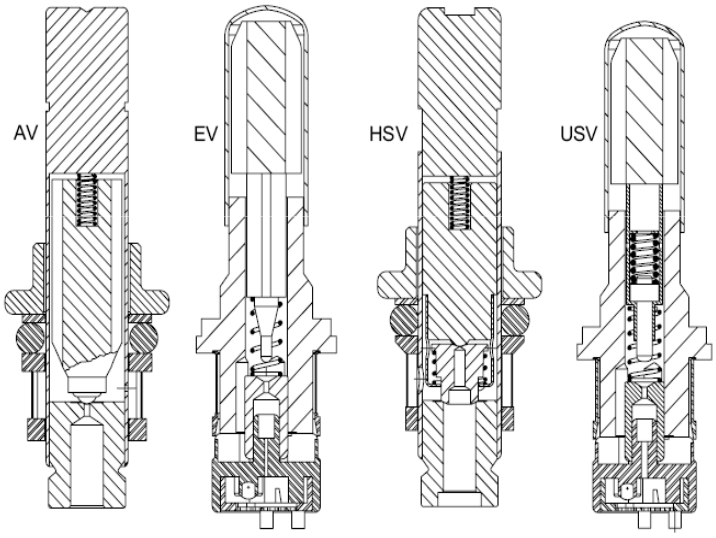
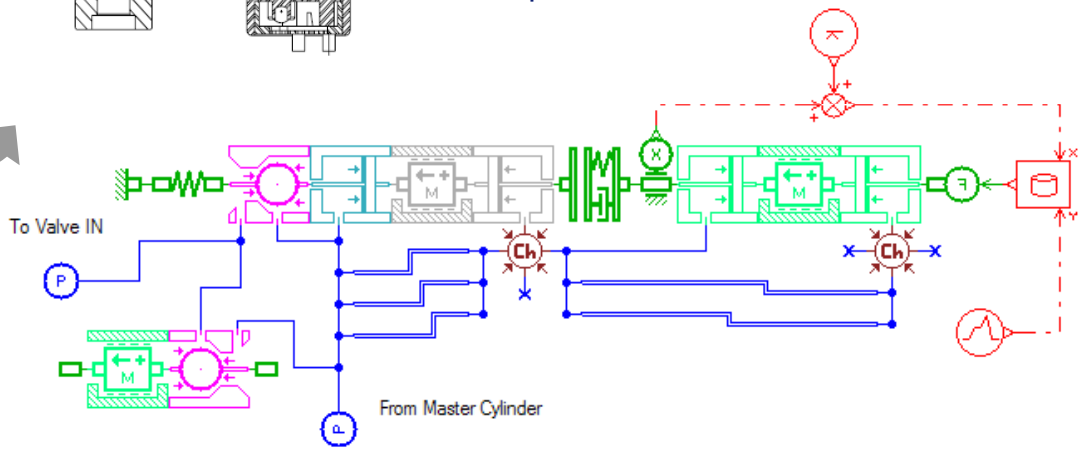
Typical ESP Valves and Detailed Model



Hydraulic Component Design

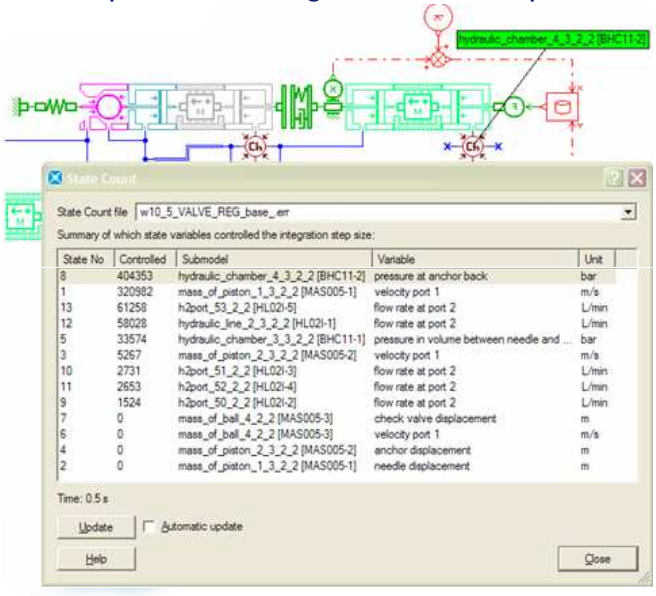
- More or less the **hydraulic valves** inside an ESP are always the same. Hydraulic libraries allow modeling **any technologies for spool or poppet valves**.
- For simplicity the **electro mechanical part** was considered as a simple Force(Current, Displacement) table, no interaction between the spool motion and the electric part.

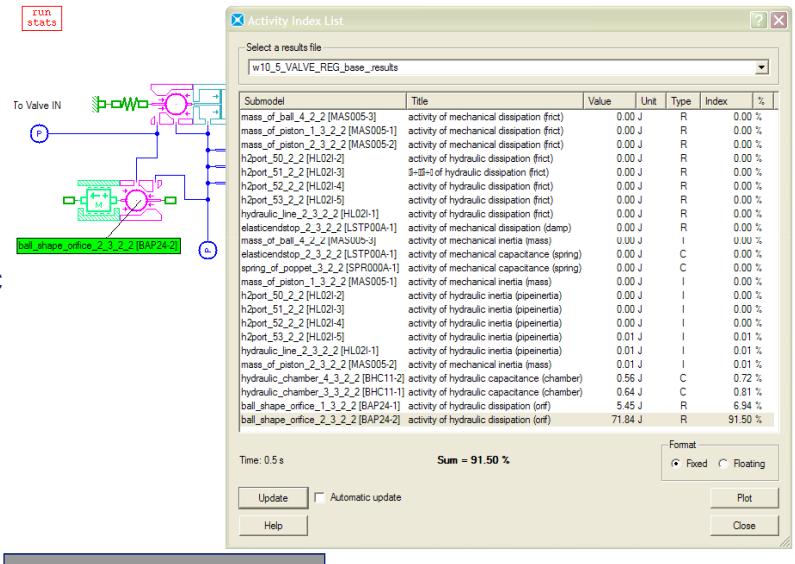


Tools for Model Simplification

State Count

- A measure of the difficulty the **solver** has to cope with particular state variables and thus an idea on which one prevents the model from **running fast**.
- Only indication on variables linked to kinetic and potential energies never dissipation





Activity index

- A measure based on the **energy exchanges** between elements. If no energy is exchanged no need to keep the physical relationship inside the model.
- An elegant way for **model simplification** but depending on the model inputs.

Tools To be Used and for What

- In order to clarify the contributions of each feature we can say that
  - the **Eigen Values** give the **frequency range** of the model,
  - the **Modal Shapes** allow having a first idea of the contribution of different power elements in the modes,
  - the **State Count** gives a view of the **state variables** that are the **most difficult to solve** (and thus probably linked to high frequency domain),
  - the **Activity Index** gives the power level stored or dissipated in the **power elements** (I, R and C-elements). If no power is stored, no need to keep the element,
  - the **Run Statistics** gives a view of the time step and the order of the method used by AMESim (Real Time target),
  - the **Fixed Step Solver** allows **validating the real time capability** of a model.

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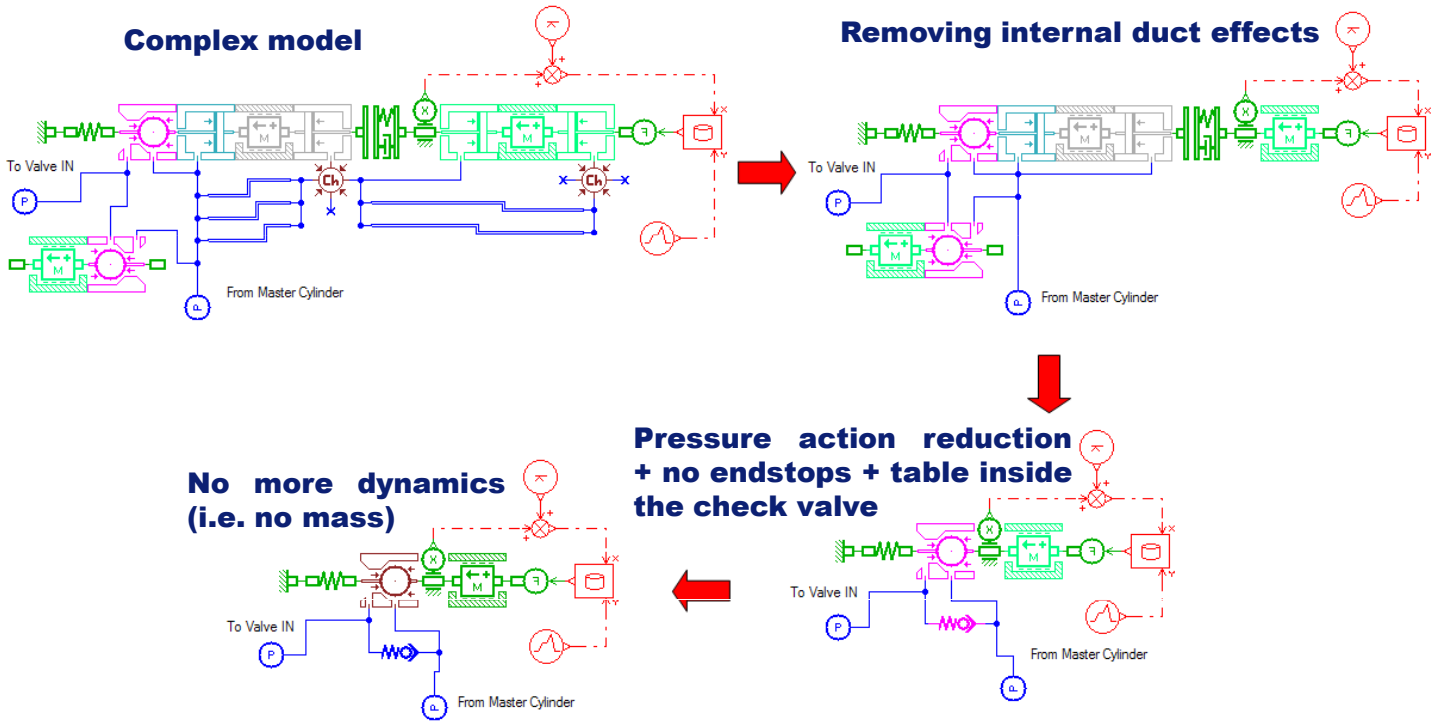
ESP Valve – Model Simplifications



- The valve model keeps its parameters and **physical sense**. It is a **pressure valve** and not a flow regulating valve.
- Since the valves are almost similar, all the valves have been simplified in the same way.

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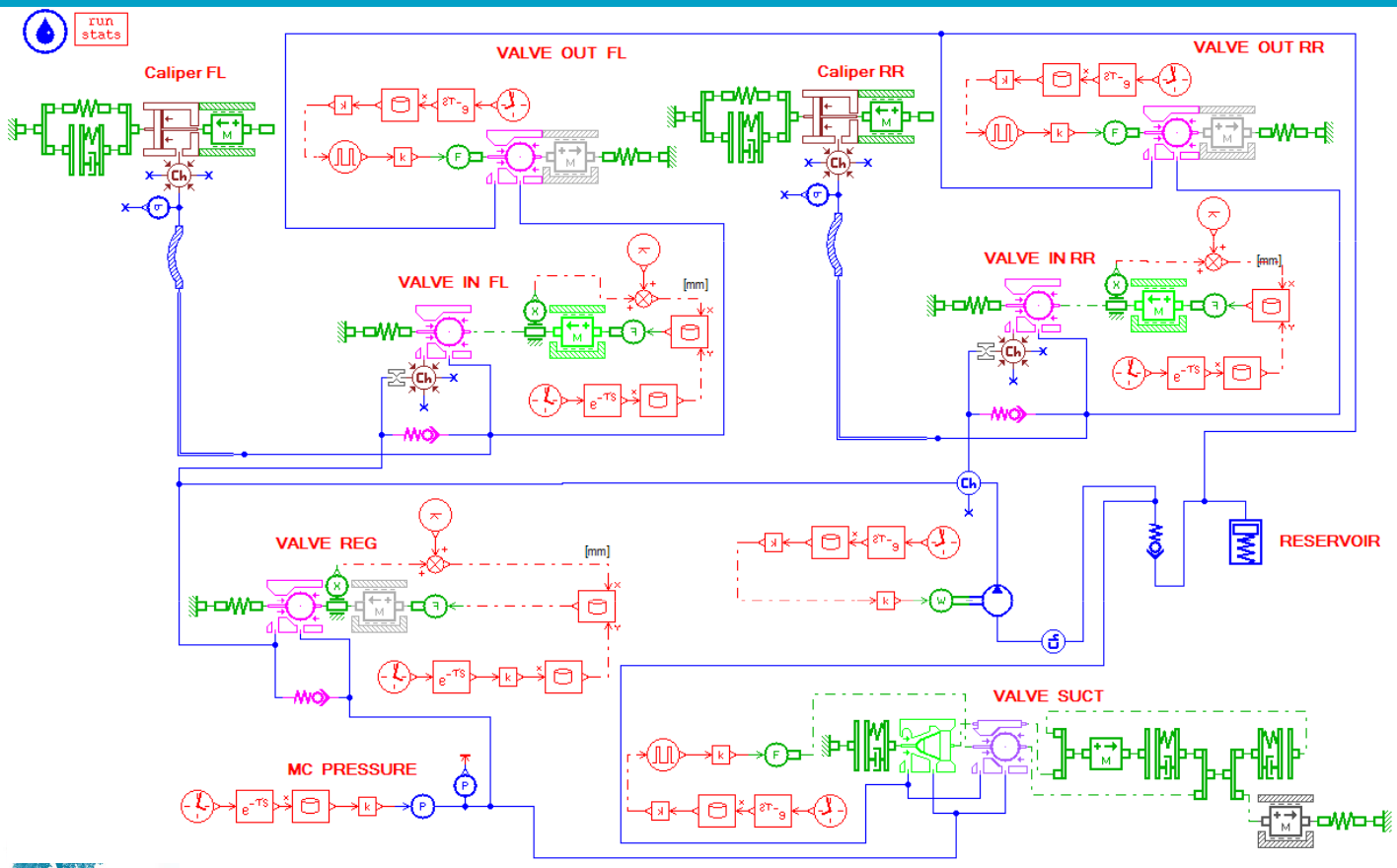
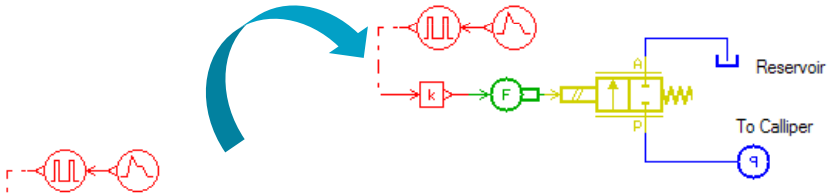
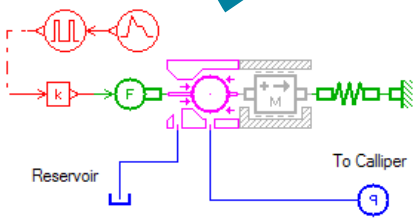
Half Braking Circuit Including all Components

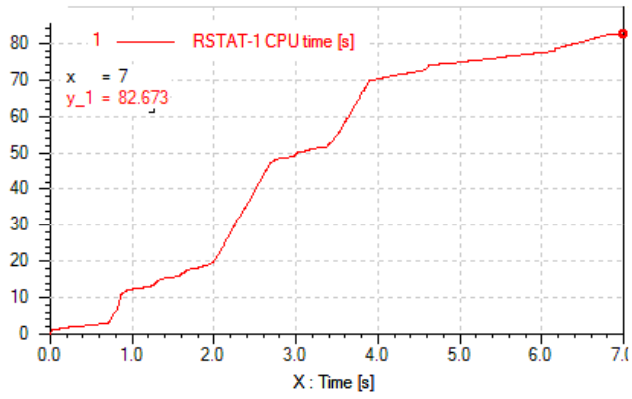


Other Model Simplifications

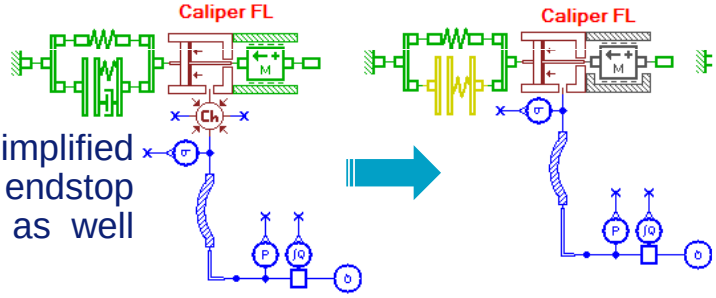
- First of all, the model includes a lot of state variables and the CPU time is not sufficiently low. Other simplifications have to be done.





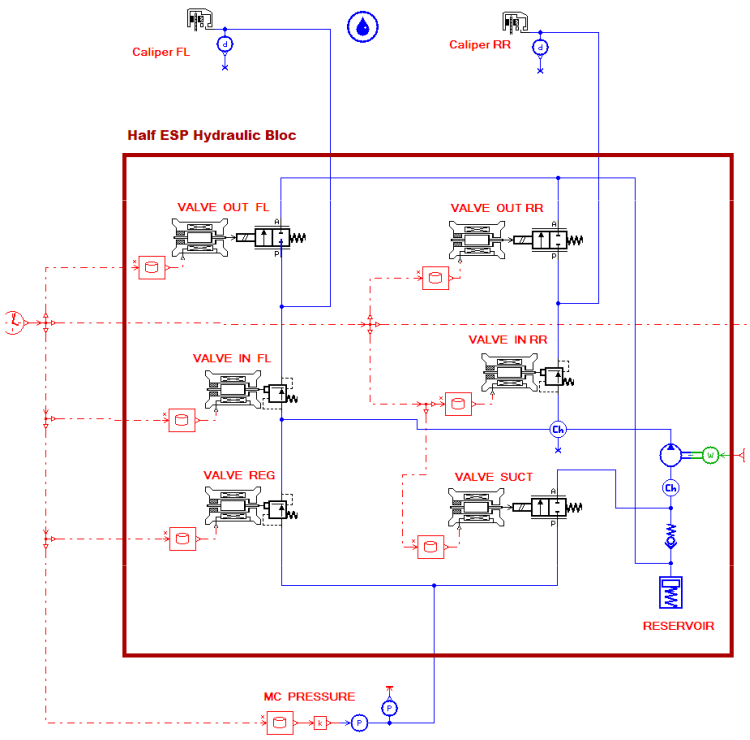


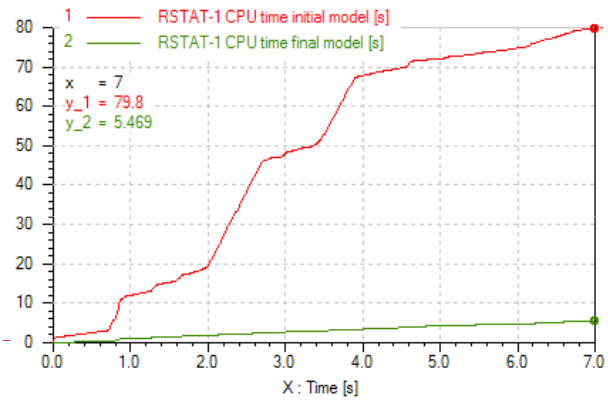
- The OUT and SUCT valves are on/off valves and can thus be simplified using the maximum opening section due to the valve geometry e.g. becoming flow valves.



- The caliper model can also be simplified using no more mass and ideal endstop models. The hose stiffness can be as well globalised.

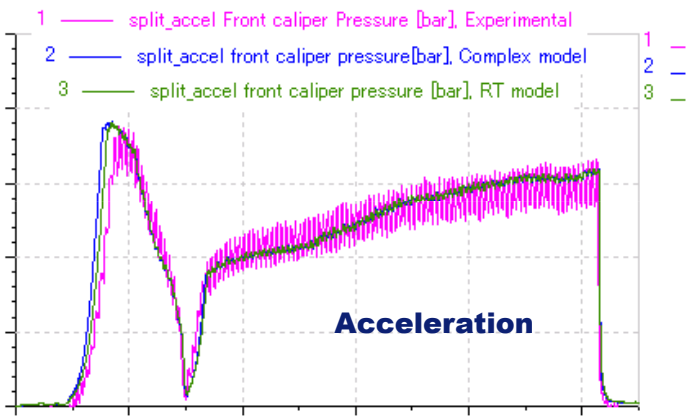
Final Half Hydraulic Circuit and its Validation





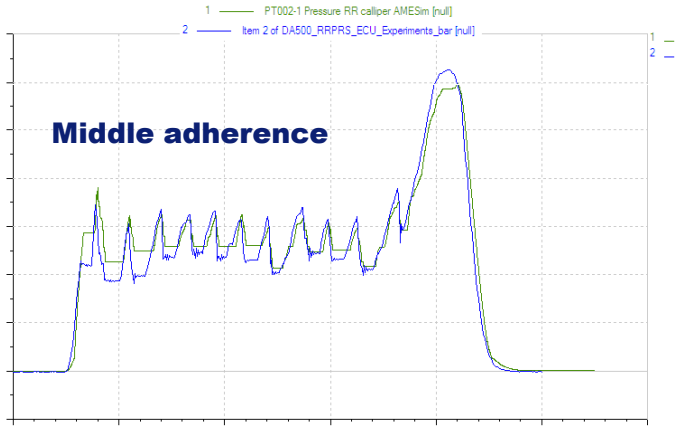
- The model finally includes additional reductions and other light modifications.
- Note that the IN and REG valves are kept as pressure components and not flow valves since they control a pressure and not a flow rate.
- The previous model was run with the AMESim standard integrator and with an Euler integrator 0.5 ms time step to check its RT ability (in AMESim).

Final Half Hydraulic Circuit and its Validation

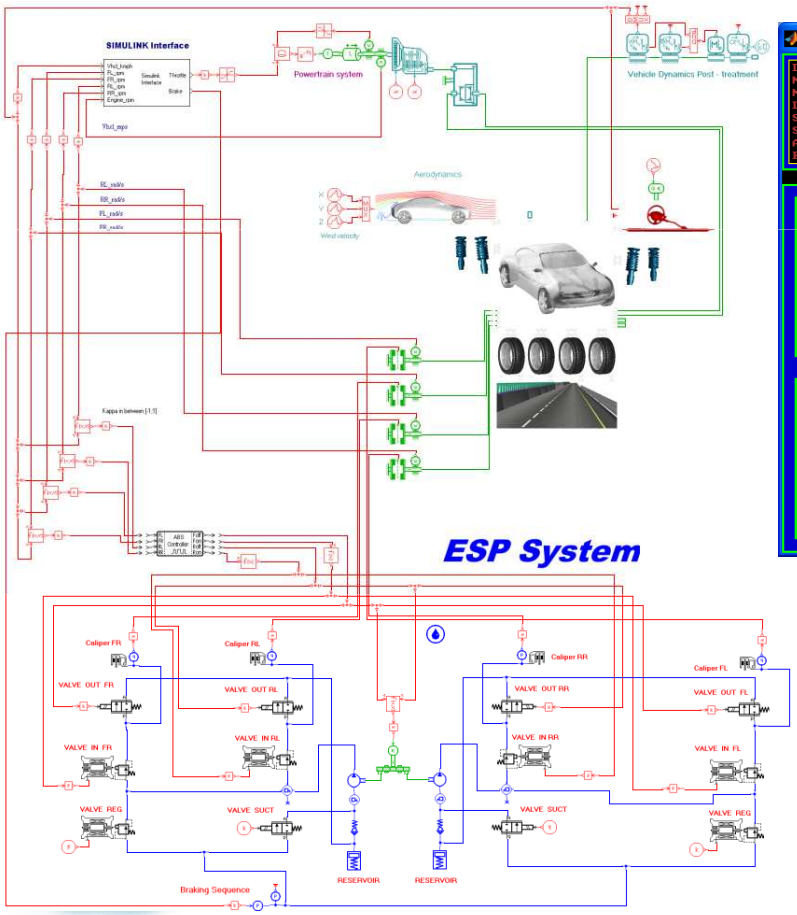


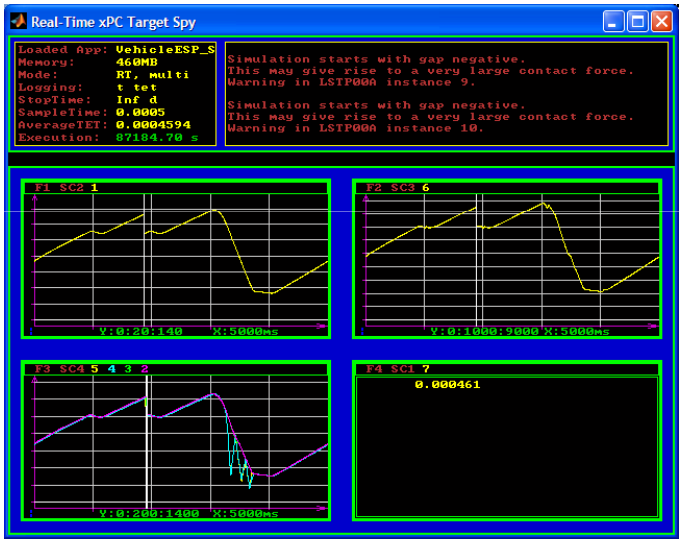
High adherence

J Turn



Real Time – Coupling Vehicle to ESP System



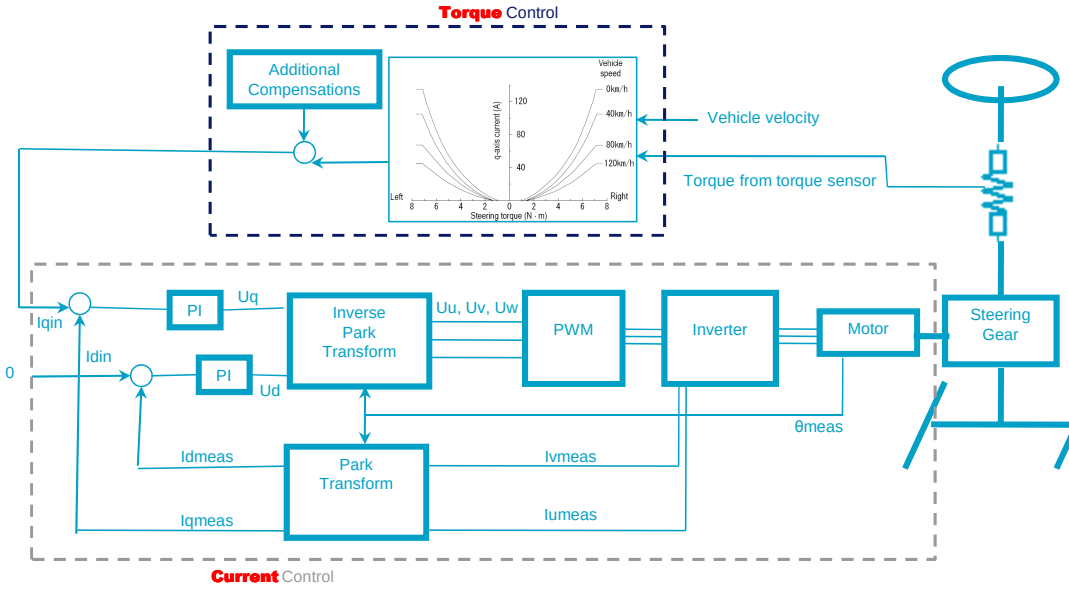


Handle high-quality control strategies on **high fidelity real time models**.

Agenda

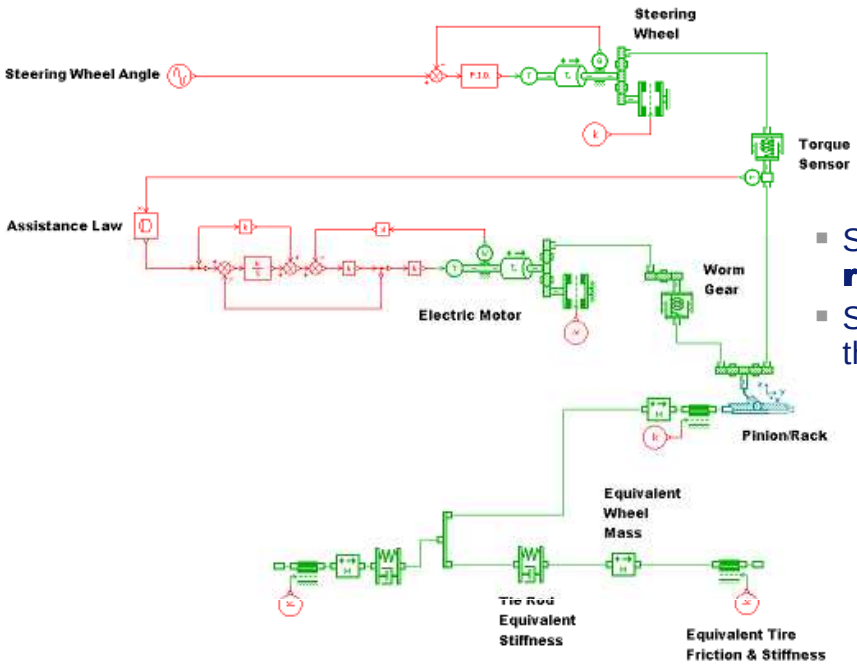
Electric Steering Systems (EPS)

- A **hierarchy** inside the controllers and who do what
  - A **control** logic dedicated to control the **torque assistance**.
  - A **control** logic dedicated to control the **motor current**.



- Depending on the request, different models can be built and of course going from the more complex to the simple can be done continuously.

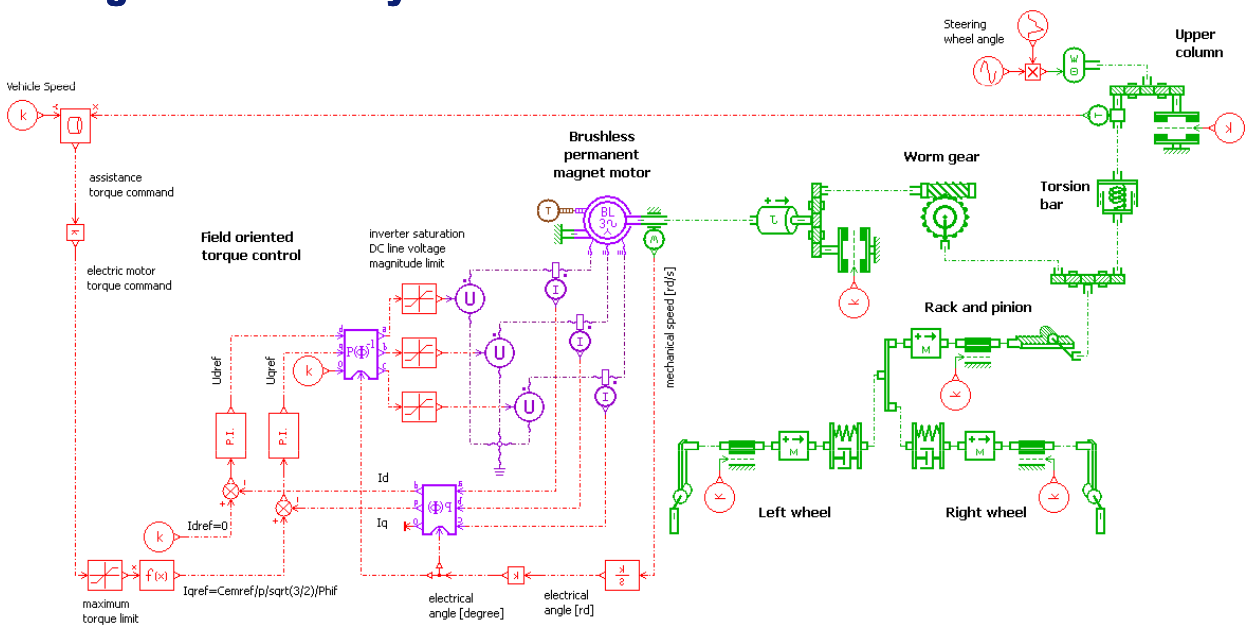
Electric Steering Systems: Modular Approach



- Simple **PI controller** and motor with its **resistance** and **torque constant**
- Simple view of the steering column and the “vehicle” (car park manoeuvre).

Electric Steering Systems: Modular Approach

- Taking into account the **technology of the motor** (Brushless Permanent Magnet Motor here) with Park transform and PI current controller.
- **Worm gear reversibility**.



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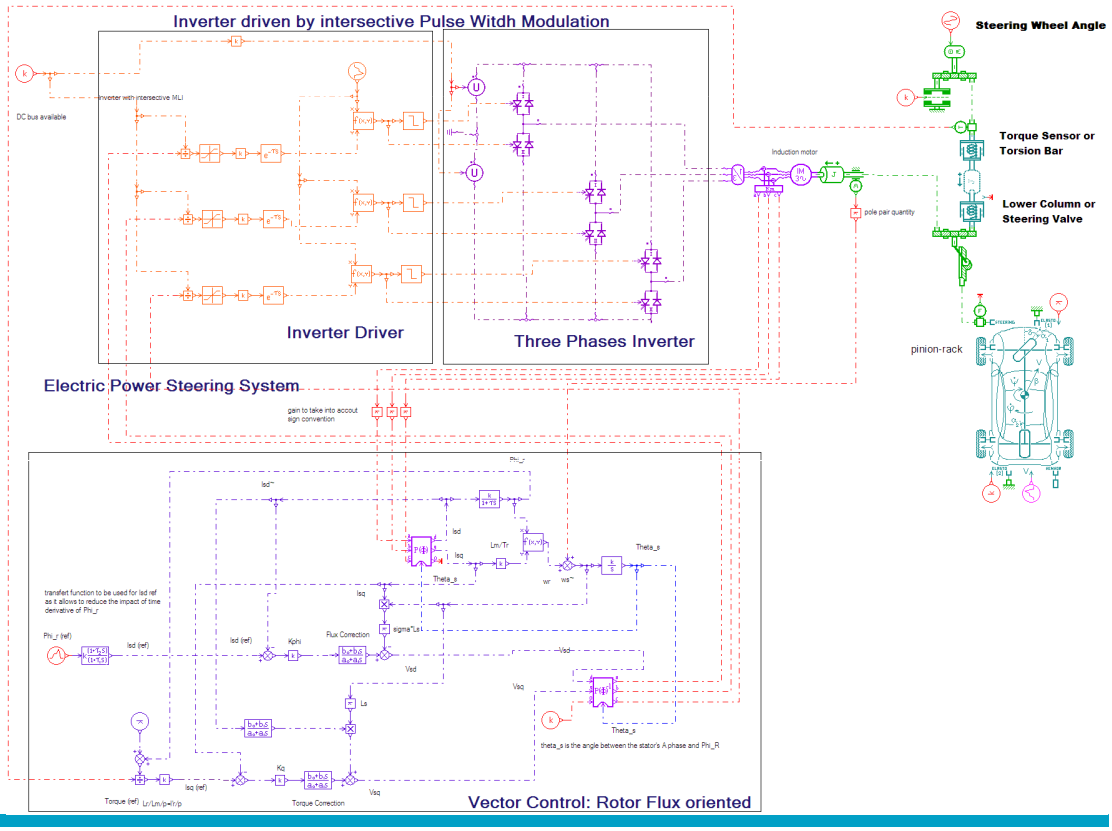
Electric Steering Systems: Modular Approach

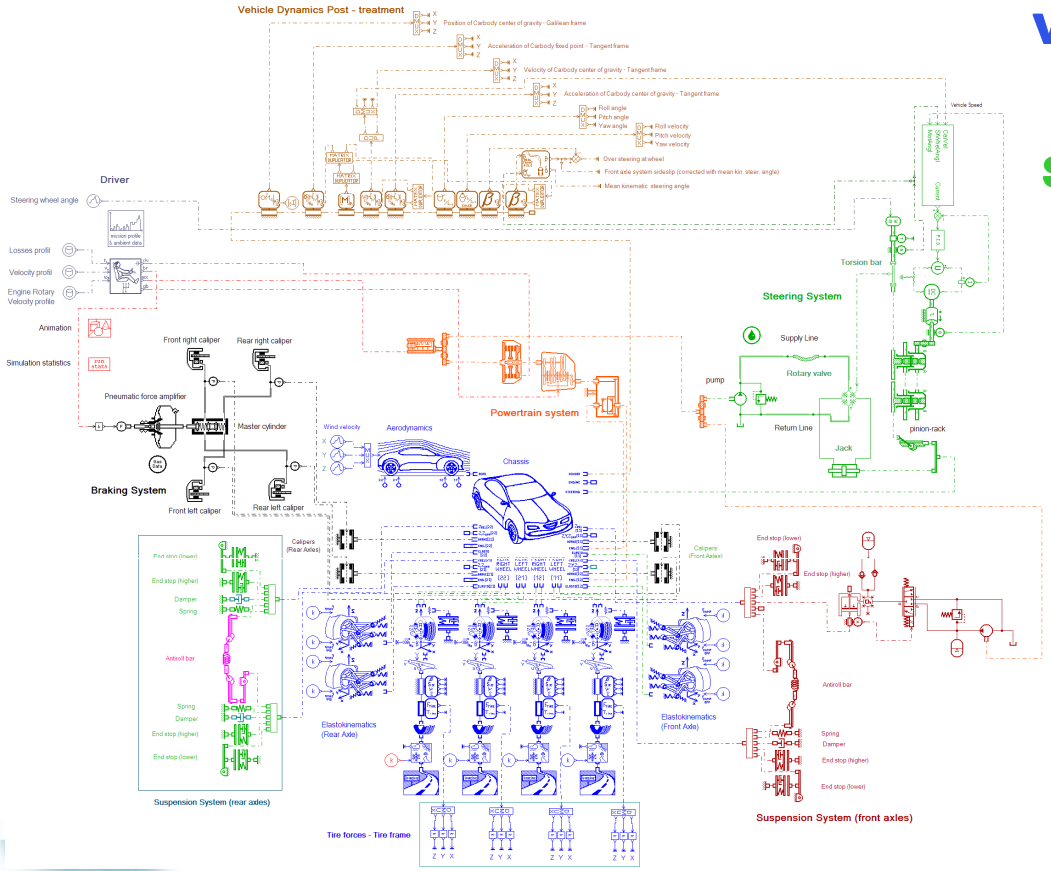
- **Power electronics** i.e. inverter, PWM generator ...
- Simple **single track model** for first view of the steering system



Agenda

1	Model Simplification - Problem Positioning
2	Braking System
3	Steering Views
4	Conclusions

The Vehicle and its Subsystems



Vehicle Dynamics

Transmission

Steering systems

Suspension

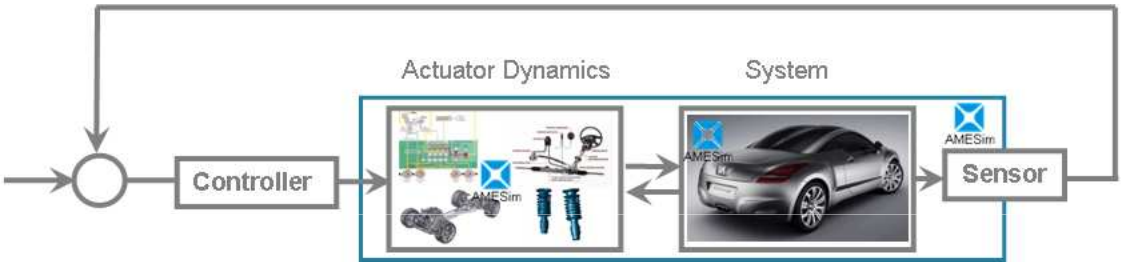
Braking circuit

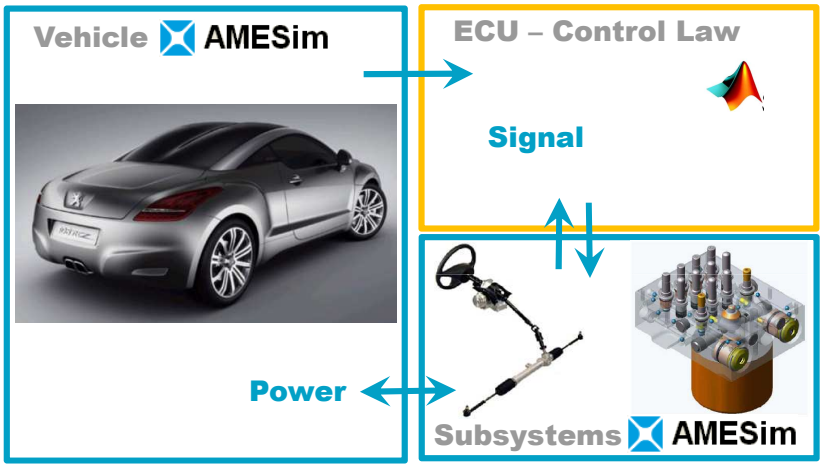
Active roll bar

Sensors

Coupling Vehicle Systems Dynamics and Transmission solutions for **driving comfort**, **ride** and **handling.**

From MiL to HiL for Controller Developments





- **MiL** for the concept phase with the vehicle in AMESim and the controller in **Simulink**,
- **SiL** in engineering phase with C code thanks to import facilities,
- **HiL** for verification phase with code Exportation to almost all the standard RT platforms.

RT-LAB Engineering Simulators · ETAS · dSPACE · National Instruments LabVIEW · MATLAB SIMULINK xPC Target · LMS Engineering Innovation

Conclusions & Remarks

- The idea behind model simplification is that **the same user can do complex and simple models** insuring the **knowledge capitalization**/transfer into the RT domain i.e. **sustainable modeling strategy**.
- AMESim provides two tools that should be used together: one giving the power exchange the other information about the solver. As well, in order to **make the simplification process continuous**, some extra models have been included into the libraries to avoid causality troubles.
- Simplifications generally result from the understanding of the system dynamics. **The design parameters and geometry remain inside the simplest model** and make the system behaves like it is i.e. **gaining technical insights** in the system of concern.
- It is for sure difficult to make **model simplification automatic**. The user should still use his brain. A software and its tools (**Engineering for engineers**) can help the users but cannot replace him (at least in 2010)!

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Thanks a lot

For Further Questions/Remarks Visit us on booth 5630

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