SIEMENS
Ingenuity for life

Simcenter for vehicle controls development

Front-loading design and validation of mechatronic-controlled systems

Benefits

- Manage controls complexity and system interactions
- Use virtual prototyping to accelerate development of controls algorithm
- Anticipate control algorithm design, embedded code implementation and ECU calibration implications based on requirements capturing and architecture selection
- Reduce the number of software iterations and physical prototypes
- Enhance digital continuity to develop vehicle control logic
- Trace vehicle control logic efficiency from concept to late refinement phase

Features

- Provide a single suite of simulation solutions that supports all stages of controls logic development
- Manage new controls development challenges with combined conventionnal and electrified powertrain capabilities
- Scale model complexity to data availability or test requirements

Summary

Environmental and safety regulations are reshaping automotive industry engineering processes in all domains, and controls engineering is no exception. The introduction of technologies that enable you to cope with regulation requirements raises the level of complexity of controls and embedded software. Software code sizes have considerably expanded over the past decade, as well as the complexity of inputs and outputs. The rise of hybridization, electrification and autonomous vehicles is drastically amplifying these phenomena. As a result of the growing trend of combining parameters, managing the conflicting calibration requirements and attributes with physical validation and testing is no longer sustainable from a cost and time perspective, and, more pragmatically, from a complexity point of view. A new approach is essential, and model-based development from early control logic definition to virtual calibration is becoming a key success factor.

Simcenter™ software helps mechanical, controls and software engineering departments to develop and validate best-in-class mechatronic systems by bringing the digital twin engineering approach – integrating simulation and test, plant and controls. The digital twin approach allows the user to better balance choices, from requirements capturing and architecture selection, including everything from early control algorithm design and embedded code development to electronic control unit (ECU) and system verification, validation and calibration. The digital twin approach enables you to roll out a concurrent mechanical, software and electrics and electronics (E/E) hardware design process and replaces expensive and time-consuming physical tests with early virtual evaluation, improving the quality of the final product and reducing development time and cost.

Closed-loop design improves plant and controls architecture selection

As soon as systems dynamics become concerns, actuators and sensors that are transient-capable must be considered. In that respect, Simcenter Amesim™ software is recognized for multiphysics system simulation (hydraulic, pneumatic, electric and combined mechanisms), including dynamic actuators and transient modeling.

Indeed, the sizing of actuation systems influences productivity such as energy consumption, dynamic response, productivity and control robustness. Using the Simcenter Amesim solution, engineers can develop closed-loop systems and compare performance or energy use early in the design process in steady-state and transient conditions. They can simulate various architectural layouts to achieve the best balance between mechanical design and control design to better deliver safety, performance, controllability and cost.

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Features *continued*

- Front-load design exploration, validation and integration throughout development
- Extend re-use of plant models to early calibration stage

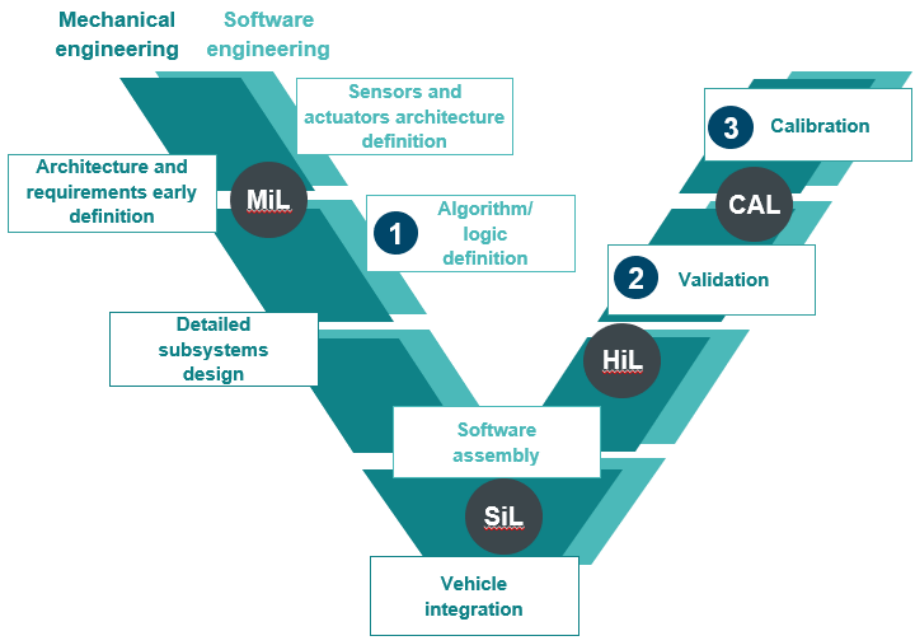
Continuously align system models and control requirements

Selecting proper model complexity at each stage guarantees model-based development methodology implementation will deliver the best return-on-investment (ROI). In other words, the model's complexity will have to align with the real-life constraints of projects, such as data availability, accuracy and real-time capabilities, avoiding oversized, slow models when accuracy is not required.

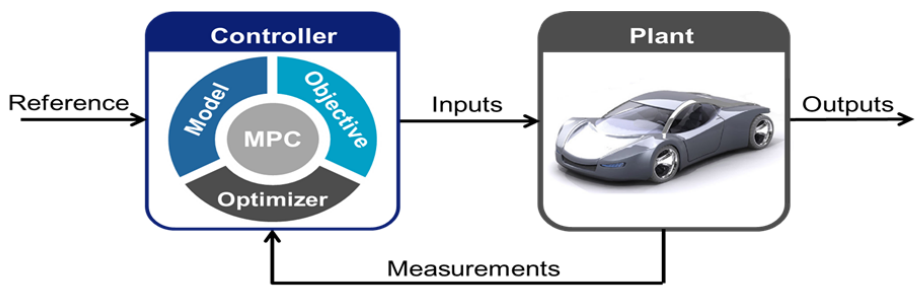
To address these challenges, Simcenter Amesim offers scalable choices for workflows to reduce model complexity when needed.

In the first stage of model acceleration, complexity can be reduced by selecting different physical modeling assumptions. Combined with numerical optimization, such a physically based model can be optimized thanks to advanced and comprehensive analysis features; for example, linear analysis, allowing users to identify constraining parts in their model.

Nevertheless, when primary physical phenomenon can no longer be reduced to fit the control requirements, users can switch to surrogate modeling approaches, such as neural networks or response surface approaches. They will get trained thanks to higher fidelity, detailed Simcenter Amesim models. It permits the user to combine all these modeling methods in a unified environment, evolving model complexity throughout the project stages.



Model-based control development cycle.



MPC closed-loop interface with plant model.

Advanced control logic design (1)

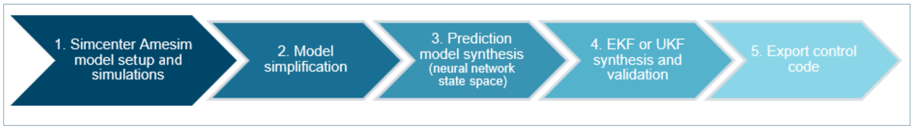
With early access to the digital twin, balancing the impact of conflicting attributes (for example, performance, efficiency, comfort, noise, vibration and harshness, emissions, etc.) can be accounted for from an early stage of design, enabling the design of smarter algorithms that will reduce tradeoffs at later development stages.

Model predictive control

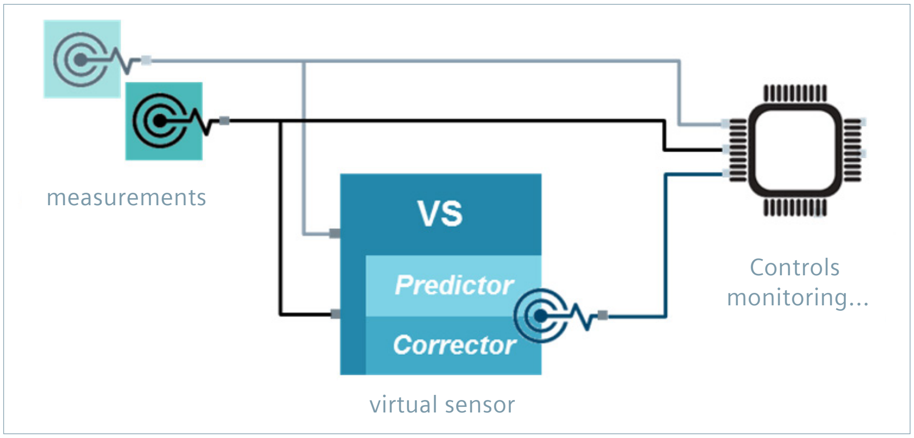
Simcenter control experts are proficient in multiple control techniques from classical methodologies like proportional-integral-derivative controller (PID) to more advanced methods such as model predictive control (MPC), dynamic programming and machine learning. Indeed, as an example, optimal control technique such as MPC or dynamic programming can be used with physical models to find the optimal power flow in your hybrid vehicle or the smoothest overtaking maneuver.

Virtual sensing
Simcenter Amesim plant models are applied to develop virtual sensing technologies. It consists of enriched system state information from physical models (when not accessible via physical sensors) to optimize the performance/robustness of the controls algorithm.

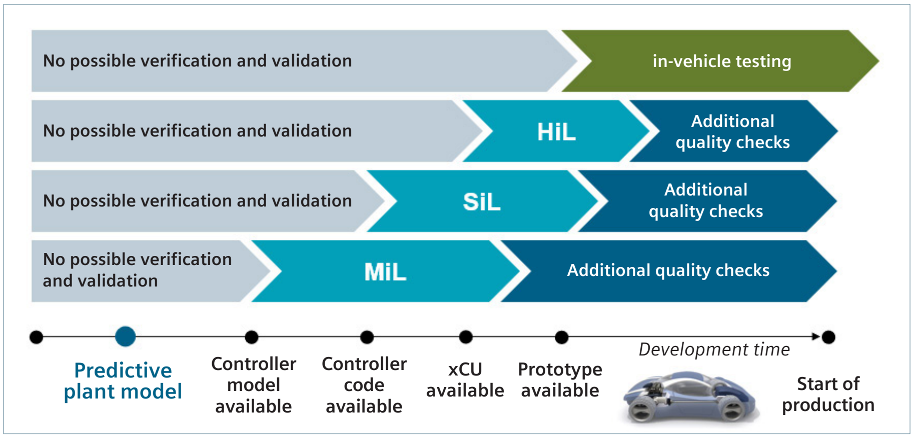
Based on multiphysics simulation software Simcenter Amesim, Siemens Digital Industries Software developed a generic and guided approach to derive automatically accurate prediction models, making them real-time compatible and synthesizing the virtual sensor. The virtual sensor can ultimately be benchmarked against the detailed Simcenter Amesim model and exported to a real-time target.



Virtual sensing algorithm design workflow.



Extend control physical measurements thanks to virtual sensors observer.



Front-loading testing thanks to digital twin system model.

Rapidly design high-quality controls

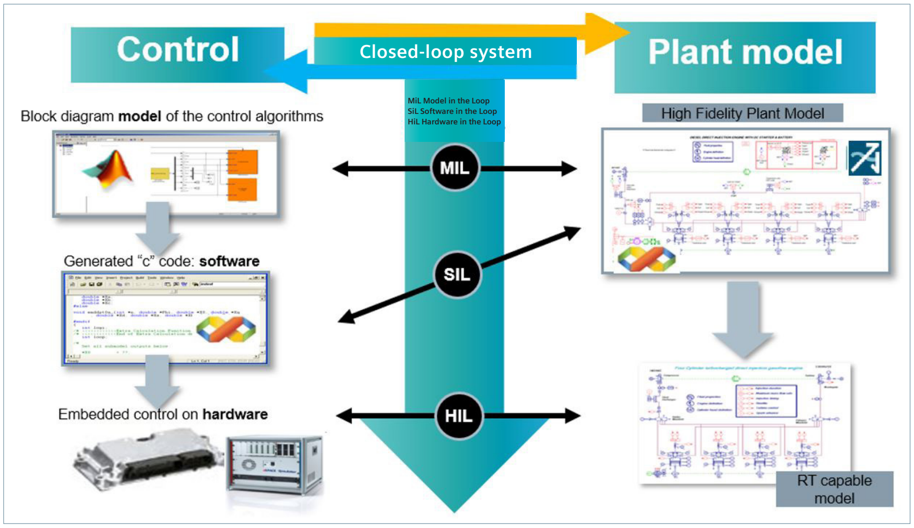
With Simcenter Amesim you get an integrated platform that provides realistic component and system models, enabling both system and control engineers to begin synchronous evaluation and validation phases early in the design cycle.

This integration can be distributed at different steps of the process – first with model-in-the-loop (MiL) or software-in-the-loop (SiL) and then with hardware-in-the-loop (HiL). Integrating plant models with a control model or code ensures the required accuracy as well as accessibility to variables needed for controls. Early evaluation and validation helps eliminate uncertainty in the development cycle resulting from integrating late in the design process.

Validation (2)

To validate the control system before machine prototypes are available, Simcenter Amesim users can take advantage of a wide range of real-time models to build a real-time simulation of their physical system and integrate the control system hardware and software with the simulation.

By developing controls earlier, the solution enables you to obtain more mature control strategies before starting the ultimate calibration phase, reducing testing time for prototypes. Ultimately, systems can be tested in unexepcted scenarios, increasing the validation coverage compared to testing prototypes.



Closed-loop testing continuity from off-line co-simulation until real-time HiL.

Virtual calibration of conflicting attributes (3)

Since behavioral models can be enough for most validation testing scenarios (see step 2 in figure 1), calibration requires more predictive and quantitative modeling capabilities. The higher fidelity Simcenter Amesim plant model can be reused at the later development stage for virtual calibration purposes (see step 3 in figure 1), tuning control parameters while reducing the dependency on prototypes. At the same time, virtual calibration will allow you to extend testing coverage for even more complex transient scenarios and possibly destructive cases.

The multiphysics background of Simcenter Amesim models can be used to optimize control strategies for conflicting attributes like fuel economy and drivability.

Testing scenarios using virtual plant models can be easily scripted for repetitive and automated testing or combined with an advanced optimization algorithm.

Ultimately, Siemens offers guidance and engineering support in the rollout of automated frameworks for verification and validation (V&V) development and early calibration.

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