TNO Mobility & Built Environment

Modular Energy Management

Cost-effective powertrain design and optimal energy consumption in any vehicles, e.g. electric, fuel-cell, hybrid

Market Challenges

Electric, fuel-cell and hybrid powertrains with more sustainable fuels are gaining increasing attention in the automotive world from the perspective of reducing CO2 emissions. In state-of-the art powertrains, multiple energy sources work together to increase the efficiency of the entire powertrain. Therefore, an Energy Management Strategy (EMS) is required to maximize this efficiency within powertrain constraints and emissions regulations.

Powertrain control calibration has traditionally been a cumbersome part of the vehicle development process, especially when it comes to wide product variations and product updates. TNO's unique automatic modularization approach has the potential to significantly reduce this development time and effort and standardize control implementation results.

Energy Management System

TNO has developed a MODULAR energy management strategy embedded in the TNO MEM Tool, which for any vehicle configuration can generate a real-time EMS algorithm, for example the one from Figure 2. The EMS minimizes vehicles energy consumption by optimizing the power settings of powertrain components within their constraints.

Modularization

The modular EMS is built from standardized powertrain modules part of the TNO MEM Tool library. Complexity is managed by the Equivalent Cost Minimization Strategy (ECMS) method and decomposing the optimization problem by using convex equations for each module.
This allows the EMS to be easily adapted, even if the powertrain topology or component type (maximum power, torque, speed, etc.) is changed.

This MODULARITY feature plays a key role in reducing development time and costs when having multiple configurations or considering new powertrain topologies for various applications.

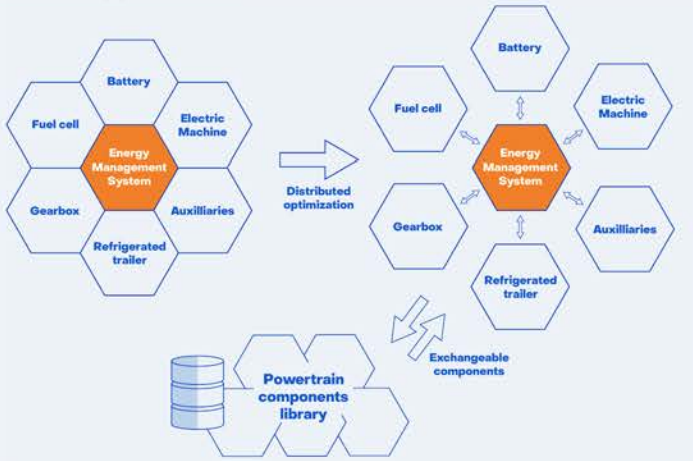

Figure 1: Converting one big optimization problem into smaller optimization problems to allow for complex configurations

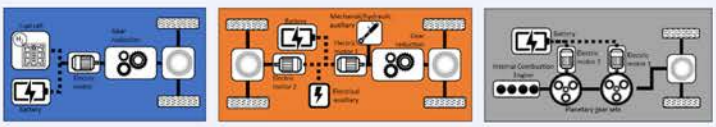

Figure 2: TNO generates energy management software algorithms for various topologies with one click.

Automatic generation of EMS

The MEM Tool calls the MEM Fit Tool GUI to parameterize the MEM powertrain components available in the MEM Tool library. Each component requires data from industry standard measurement procedures and component specification sheets, so no need for dedicated test programs.

Why TNO?
TNO is an international leading research & development institute in the field of efficient and sustainable powertrain systems that optimize overall system performance for both the on/off-road and maritime transport industry. At TNO, we combine proven expertise, innovative concepts, efficient development tools and world class test facilities.

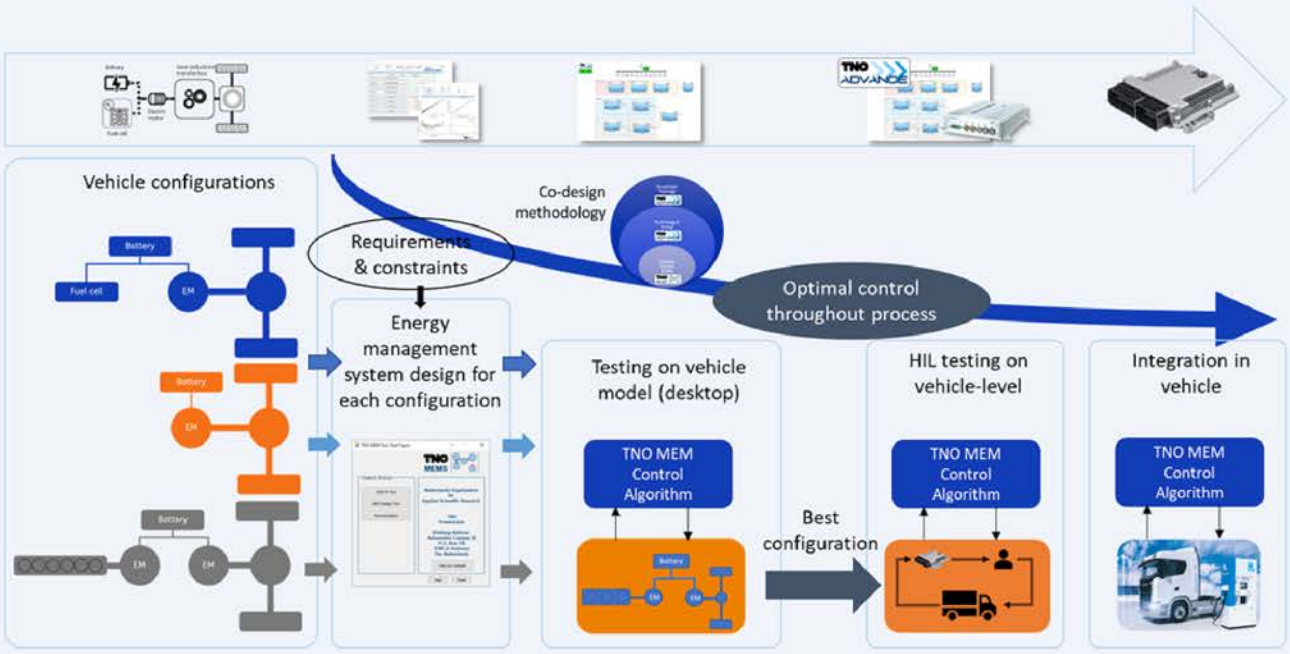

Figure 3: TNO MEM algorithm used throughout the development process.

Using the other GUI of the MEM Tool, e.g. the MEM Design Tool supports the user to automatically generate an EMS algorithm after definition of the powertrain topology and component selection. The output of the MEM Tool is a MATLAB Simulink EMS algorithm, which can directly be embedded in the specified powertrain.
This generated EMS requires commonly available signals such as component rotation speed, power demand from drivers, power demand from auxiliaries and battery state of charge.
The generated EMS can be calibrated to maximize energy efficiency for customer-specific driving missions.

Benefits

The main benefits of TNO's MEMS are: - The MEM control algorithm optimizes energy consumption and is unique due to its modular framework, featuring MATLAB tools to automatically generate an EMS. - The MEM EMS algorithm is an open adaptable architecture, making it an excellent foundation for in-house adoption. - The MEM Tool is MATLAB Simulink based and compatible with recent versions (e.g. R2021B and above). - Modularization of the MEM Tool reduces development time and costs for controlling complex sustainable powertrains. - Leverage the modularity of the MEM Tool and EMS algorithm to add customer-specific subsystems – The MEM algorithm enable quick and unbiased comparisons of different sustainable powertrain configurations. In conjunction with TNOs ADVANCE modular simulation environment, fast and efficient system performance evaluations can be conducted.

TNO ADVANCE with Powertrain Suite library

Verification and validation of the generated EMS algorithms can be done using customers plant models or with TNO's modular simulation environment called TNO ADVANCE with the Powertrain suite library containing components like engine, electric machine, fuel-cell, battery, etc.
It allows the customer to quickly set-up a plant model in MATLAB/Simulink, run various simulation scenario's and perform data analytics to evaluate the system/control performance.

Track record

The modular EMS has been created from scratch since 2014 and is being further developed in the European H2020 project. In has been used in applications such as multimodal hybrid buses, distributed hybrid trucks, fuel cell vehicles, construction machinery, and EMS has been tested on a virtual truck simulation platform.
Over time, the TNO MEM Tool has evolved and several non-road and heavy-duty customers adopted it into their development process and/or embedded the MEM algorithm into their control platform.

TNO proposal

Please contact us for additional information, and start the dialogue about the TNO MEM Tool adoption into your organization.

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