

Modular Energy Management

COST EFFECTIVE ENERGY CONSUMPTION OPTIMIZATION FOR HYBRID VEHICLES

TNO innovation for life

Market Challenges

Hybrid powertrains are increasingly in the centre of attention in the automotive world, due to the promising horizon of lower CO2 emissions. In hybrid powertrains, multiple energy sources work together to increase the overall powertrain efficiency. This requires an energy management strategy (EMS) that optimizes this efficiency within the powertrain constraints and emission requirements. Developing the EMS is therefore complex, labour-intensive and differs for every vehicle configuration.

Energy Management System

TNO has developed a Modular Energy Management Toolbox for hybrid vehicle configurations. This toolbox can be used to develop the EMS, which minimizes the vehicle energy consumption by optimizing the power setpoints of the powertrain components, while satisfying physical constraints, e.g. components' power, torque and speed limitations.

Modularity

The EMS is built up from standardized optimization modules in TNO's Toolbox for supervisory control. The complexity is managed by the Equivalent Cost Minimization Schedule (ECMS) method.

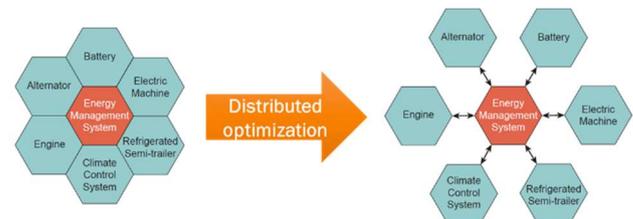


Fig. One large optimization problem converted into small optimization problems related to each component.

This allows the EMS to be easily adapted when the powertrain topology and/or component sizes (i.e. maximum power, torque, speed, etc.) are modified. This MODULARITY feature plays an important role in reducing the development time and cost, when exploring new powertrain topologies for different applications.

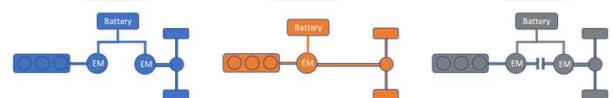


Fig. TNO generates Energy Management System software for many different topologies with one mouse click.

Automatic EMS Generation

The toolbox is equipped with a feature to automatically generate the EMS based on the powertrain topology of the vehicle. This requires the user to define the powertrain topology with the MEM

Why TNO Traffic & Transport?

TNO is an international leading research & development group in the field of efficient and sustainable powertrain systems that optimise 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.

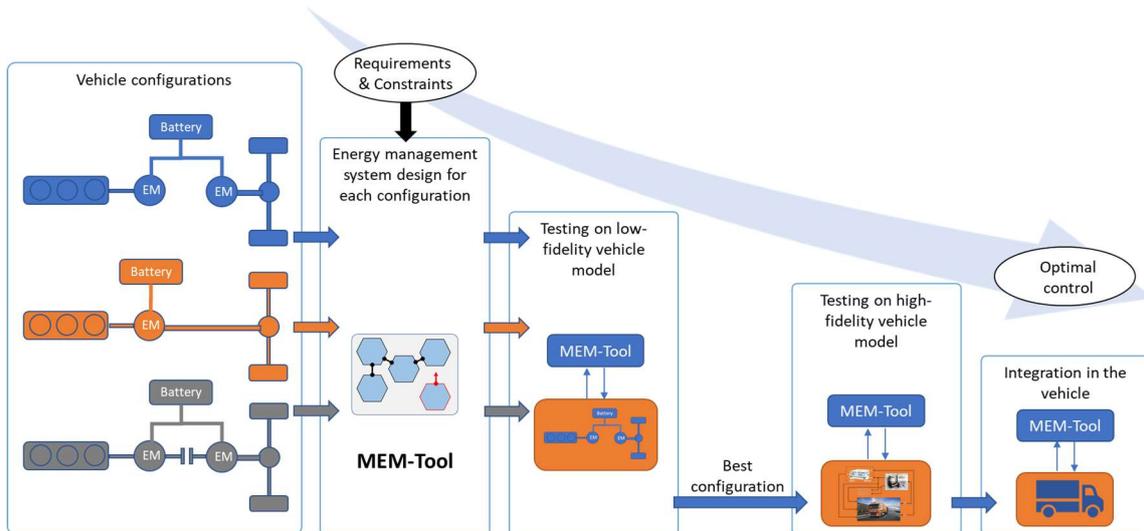


Fig. Automatic generation for energy management strategies allowing reliable comparison of configurations in an early stage of development.

Graphical User Interface. An automated process will subsequently generate the Matlab Simulink model for the EMS, which can directly be integrated within the specified powertrain model.

The generated EMS requires typical available signals such as component rotational speeds, power demand from the driver, power demand from auxiliaries, and the battery State of Charge.

The generated EMS can be calibrated to maximize the energy efficiency for the customer specific driving mission.

Main benefits

Main benefits of TNO's EMS are as follows:

- The EMS toolbox optimizes energy consumption, is unique due to its modular framework and is equipped with an automated Matlab tool to automatically generate the EMS.
- The EMS toolbox is open architected (no black box content), and therefore an excellent starting point for future internal development
- The EMS toolbox is developed in Matlab Simulink (version 2015b and up)
- The modularity of the EMS toolbox reduces development time and costs for control of complex hybrid powertrains
- The modularity of the EMS toolbox can be utilized to add the control of customer specific subsystems

- The automated Matlab tool allows for fast and fair comparison of different hybrid configurations and topologies, potentially leading to more and closer interaction with end-customers.

Calibration of the hybrid control is traditionally a cumbersome part of the development process for hybrid vehicles, and particularly dominant over a wide range of product variants, and/or product updates. TNO's unique automated modular approach has the potential to significantly reduce this development time and effort, as well as standardising the control implementation outcome.

TNO's proposition

TNO would like to get in touch with partners who are aiming to develop their own modular energy management platform. The TNO EMS can give them a perfect head start.

Track Record

The EMS has been created from scratch since 2014, and has been further developed in a European H2020 project. It has been used in applications like multimodal hybrid buses, distributed hybrid trucks, FCEVs, Non-road mobile machinery and the EMS is tested on a virtual truck simulation platform.

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