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Co-Design of Advanced Powertrains through Modular Energy Management

Creating Automated Control Generation for Innovative Powertrains

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The complexity of designing powertrains for non-conventional vehicles presents new challenges in terms of topology, component sizing, and optimized control. Often the design space for these systems is significantly large, and the amount of time required to produce optimized control over a product family presented significant development costs to OEMs. The approach of Modular Energy Management (MEM) is aimed at both exploring the design space for these vehicles, as well as producing optimized control regimes automatically. This paper presents the MEMs approach as part of an overall co-design approach, including case studies on the potential towards powertrain optimization.

One of the particular challenges in developing these systems is the very large design space, which rapidly increases as a product of the choices of topology, component technology, component sizes, and energy management approaches. Even for a fairly limited number of components, this process often becomes unmanageable without the use of customized design tools. Both the plant and its controller should be integrated into the design process to ensure and overall optimum system design; the practice of so-doing is often referred to as a co-design methodology.

MEMs builds from the Equivalent Consumption Minimisation Strategy (ECMS), which is a well-known strategy to solve the energy management problem for hybrid vehicles, or those including more than one energy source. Typically, ECMS will be combined with an objective function which seeks to minimize fuel consumption, or minimize fuel consumption along with emissions. In the case of minimizing the fuel consumption, the objective function is defined in terms of the power of the internal combusition engine.

In order to facilitate the modular energy management approach described in this paper, all components must be modelled in a convex manner such as to guarantee achieving an optimal solution.

In order to solve the optimal control problem, it is desirable to split via dual decomposition. This methodology allows for a generic solution, regardless of the powertrain topology. In this way, the MEMS approach can be used for solving any powertrain topology, without the need for reformation of the problem within ECMS.

MEMs is used as part of the co-design process, overcoming the barrier of time-consuming activities around optimal control generation. MEMs is combined in an co-design approach which generates topologies and sizing of components. The outer optimisation approach is not presented in this paper, but utilizes a layered optimisation scheme, able to do with both continuous and discrete optimsation variables.

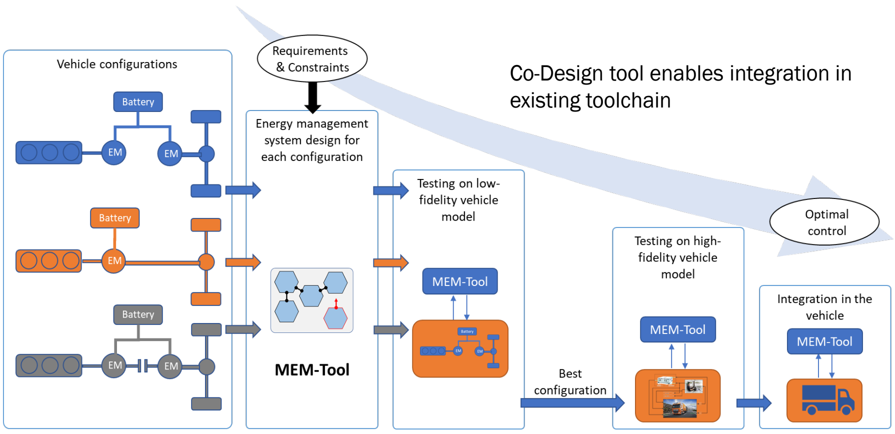

Fig 1. Conceptual Workflow Approach

Moreover, the implementation of MEMs is briefly presented and discussed, highlighting the ability to automatically generation control code, which has major advantages within the automotive design process. Several of the highlighted tools, including the open-source simulation environments are aimed at providing the MEMs approach to a wide variety of end-users.

Finally case studies have been presented for some of the tests of the MEMs approach. These use-cases highlight the flexibility, integration within co-design, and real-time capabilities for the approach.