HAW HAMBURG
Hochschule für Angewandte Wissenschaften Hamburg; Department Fahrzeugtechnik & Flugzeugbau

Virtual powertrain design in automotive development

Candidate: **Lukas Priebe-Keller**, lukas.keller@haw-hamburg.de
Tutor: Prof. Dr. Antonio García Martínez, angarma8@mot.upv.es
Supervisor: Prof. Dr.-Ing. Thomas Netzel, thomas.netzel@haw.hamburg.de

UNIVERSITAT POLITÈCNICA DE VALÈNCIA
Programa de Doctorado en Sistemas Propulsivos en Medios de Transporte

Motivation

In the automotive industry virtualization of powertrain development and testing, i.e. virtual prototyping, is steadily increasing. To benefit most from the virtual prototyping, the required simulation models must be available early in the development process. The application of early virtual prototyping is also called Frontloading, which on successful application requires fewer hardware prototypes and eventually allows cheaper and faster development. With virtual prototyping, for example, it is possible to analyze and optimize complex powertrains with a large amount of parameters. Thus it can support decision making at an early stage of development. This study shows one way to design a powertrain of a plug in hybrid electric vehicle using DoE methods to evaluate a parameter study. The results of this powertrain design must serve as visual proof to show the optimization potential. If the development process in industry is taken into consideration, employees with different skills and expertise will come together to develop the powertrain. A clear and understandable visualization helps those involved and supports decision making.

Objectives

- Simulation model uses kinematic simulation approach and black box modelling
- Agile teamwork between the simulation creator, simulation user, DoE expert and test bench engineer
- To design the powertrain a parameter study is conducted
- Evaluation and visualization of the parameter variation with DoE polynomial models

Modelling

To model the vehicle a kinematic modelling approach is used to estimate the energy usage of the powertrain under investigation. All relevant components of the powertrain and the energy/signal flow are visualized in **Figure 1**. Due to the required low complexity of the modelling, the engines and the inverter are represented by black box models, which are determined experimentally with the help of the engine test bench at the HAW Hamburg. The engine test bench shown in **Figure 2** represents a hybrid powertrain with an asynchronous machine and an internal combustion engine that is used for data acquisition and validation. The test bench can be controlled with a prototyping unit. This enables engine in the loop testing to develop energy management strategies, control strategies, et al.

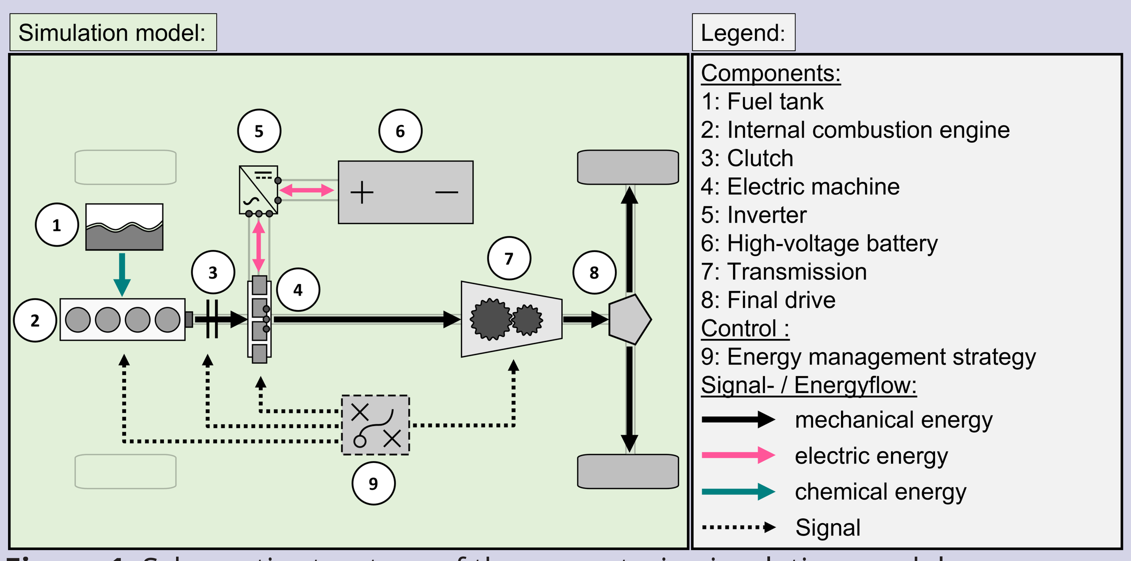

Figure 1: Schematic structure of the powertrain simulation model

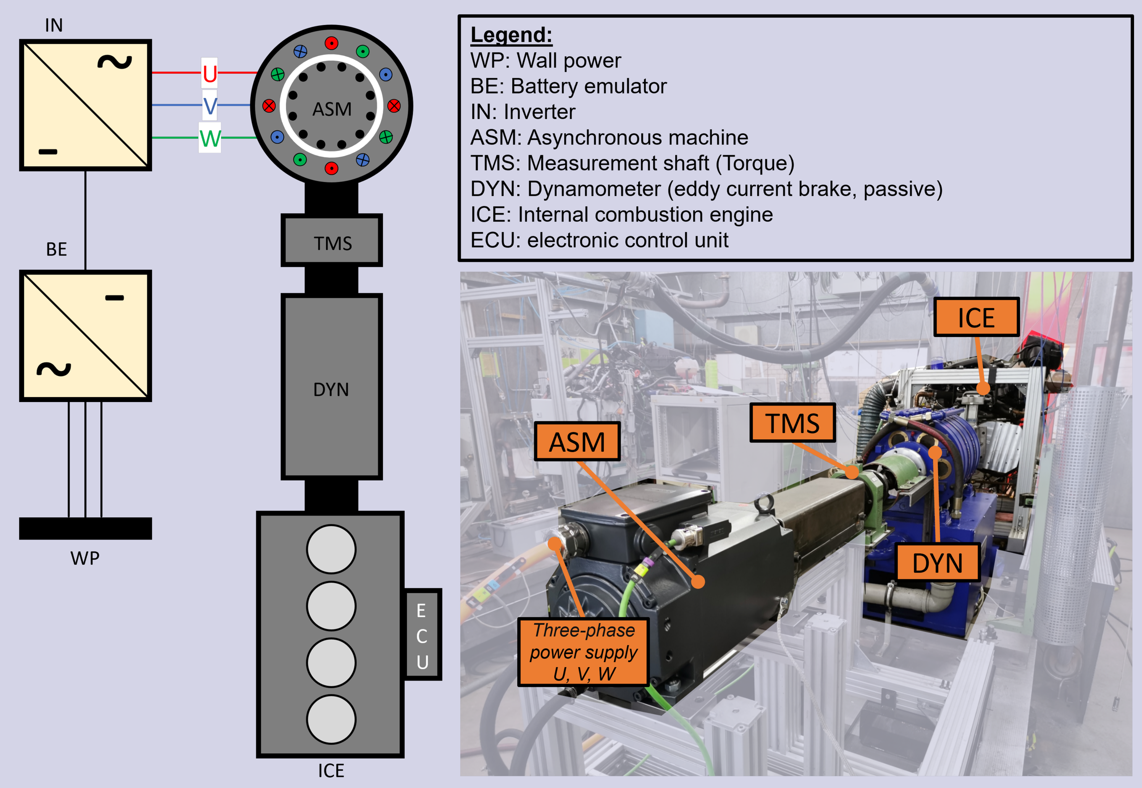

Figure 2: Engine test bench of a hybrid powertrain at the HAW Hamburg

Parameter study

The analysis of the parameter study is shown in **Figures 3a - 3d**. The parameter space and the target quantities are listed in **3a**. To allow a general statement of the energy efficiency of the hybrid powertrain the cumulative corrected CO_2 emissions are implemented. These CO_2 emissions are calculated from the local CO_2 emissions arising from the internal combustion engine and from the electric energy generation, that would be needed to compensate the battery energy used. In **3b** the average trend of the target quantity is visualized by the respective parameter, which provides an initial indication of the potential for optimization. The **Figure 3c** shows an 2D-interaction plot of the variables battery energy (BE) and starting state of charge (SSOC). Interactions are fundamental to understand system behavior and estimate further optimization potential. Lasty, in **Figure 3d** a contour plot of all target quantities is presented. Contour plots show the influence of two parameters on the target quantity in a manageable way in the parameter space and allow robust optima to be identified by low gradients around the optimal point.

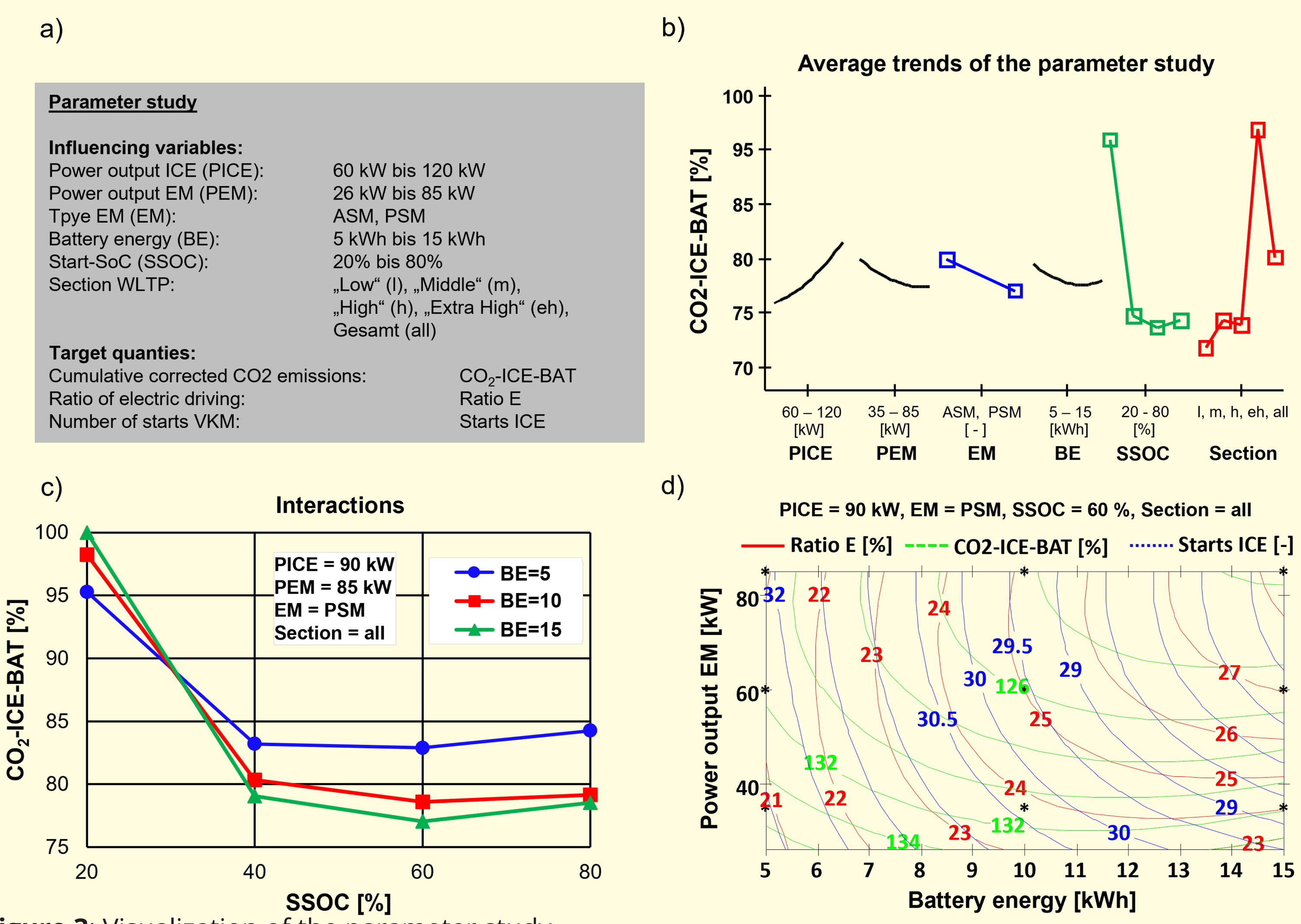

Figure 3: Visualization of the parameter study

Conclusion

- In this use case the simplified kinematic, black box modelling approach is sufficient to design the powertrain and estimate the CO_2 emissions
- Agile teamwork with weekly-monthly status reports and spontaneous troubleshooting when necessary was essential
- Evaluating a parameter study with DoE methods is very thorough, but needs a DoE expert