

# Powertrain design sensitivity study of a heavy-duty hybrid electric truck

**Citation for published version (APA):**

Verbruggen, F., & Hofman, T. (2018). *Powertrain design sensitivity study of a heavy-duty hybrid electric truck*. 83. Abstract from 37th Benelux Meeting on Systems and Control 2018, Soesterberg, Netherlands. <https://www.beneluxmeeting.nl/2018/uploads/papers/boa.pdf>

**Document status and date:**

Published: 01/03/2018

**Document Version:**

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Powertrain design sensitivity study of a heavy-duty hybrid electric truck

F.J.R. Verbruggen, T. Hofman

Control Systems Technology, Eindhoven University of Technology, Den Dolech 2, 5600 MB Eindhoven, The Netherlands

Email: f.j.r.verbruggen@tue.nl, t.hofman@tue.nl

## 1 Introduction

Most of the research related to powertrain design focuses on finding the optimal design under given conditions. However, only limited research is focused on the design space around this optimum, which would be interesting in order to determine the robustness of the optimum found. This creates insight into the sensitivity of the optimal performance to variations in the design and/or conditions of the vehicle. This is crucial for research into the design of 'modular' powertrain components, components designed for multiple vehicle segments.

## 2 Sensitivity studies

Multiple types of sensitivity studies are available, ranging from one-factor-at-a-time (OAT) to variance based methods. Since the purpose of the use of sensitivity studies here is in the first phase of vehicle design, high computational expenses should be avoided. Therefore, computational inexpensive, but still accurate enough, sensitivity studies are preferred. In this work, discussed in more detail in [1], a sensitivity study based on a two-level factorial design is performed on a hybrid electric heavy-duty truck.

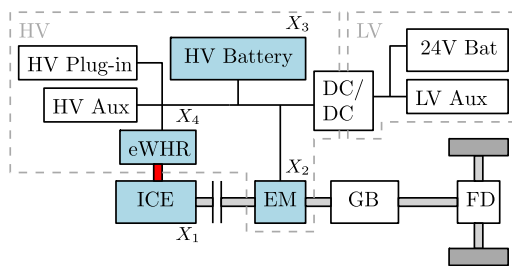


Figure 1: Topology of the vehicle studied [1].

## 3 Two-level factorial design

The vehicle studied is a parallel hybrid plug-in heavy-duty truck. The vehicles topology is shown in Figure 1. The factors studied are indicated in blue, which are: sizing of the internal combustion engine ( $X_1$ ), electric machine ( $X_2$ ), and battery ( $X_3$ ), and the presence of a WHR system ( $X_4$ ). The objectives studied are: ( $f_1$ ) the fuel savings, ( $f_2$ ) powertrain efficiency, ( $f_3$ ) energy generated by the WHR system, ( $f_4$ ) reduction in total cost of ownership, and ( $f_5$ ) the average torque split.

The research leading to these results has received funding from the European Community's Horizon 2020 Programme under grant agreement No. 653468 (ECOCHAMPS).

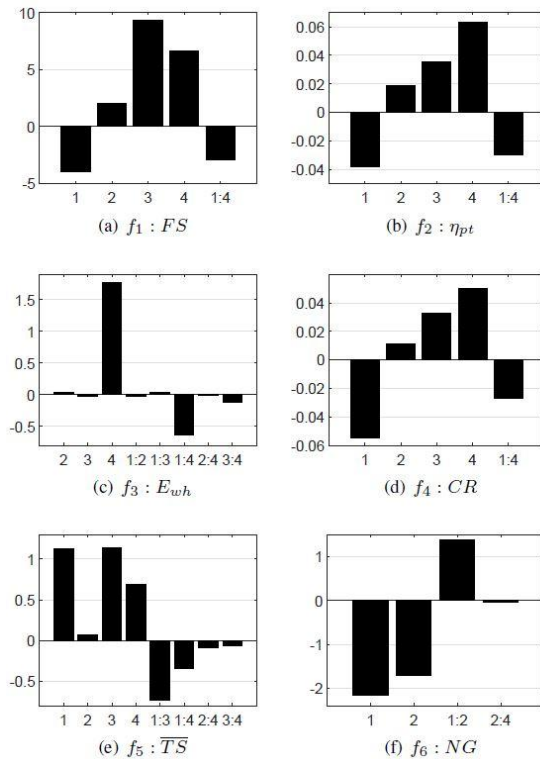


Figure 2: Plots of significant regression model parameters for each of the six objectives studied [1].

The method is based on a two-level factorial design, where for each factor studied two levels are simulated. For each of the objectives a linear regression model is fitted w.r.t to the four factors. A more detailed description of the method can be found in [1]. The significant regression model parameters are plotted in Figure 2.

## 4 Conclusions

The main conclusions that could be drawn for the vehicle studied using this method, and visible in Figure 2, are:

- Non-optimal vehicle design w.r.t. cost and fuel
- Cost effective WHR system
- Significant coupling between ICE and WHR

## References

- [1] F.J.R. Verbruggen and T. Hofman, "Design sensitivity analysis for heavy-duty hybrid electric trucks with a waste heat recovery system," in Proceedings of Vehicle Propulsion and Powertrain Conference, Belfort, France, 2017