Techno-economical System Optimisation and Its Application to an Energy System

M.Sc. Mario Holl, *Chair of Fluid System, TU Darmstadt, mario.holl@fst.tu-darmstadt.de*
Prof. Dr.-Ing. Max Platzer, Department of Mechanical and Aerospace Engineering, University of California Davis, maximilian.platzer@gmail.com
Univ.-Prof. Dr.-Ing. Peter Pelz, Chair of Fluid System, TU Darmstadt, peter.pelz@fst.tu-darmstadt.de

Keywords: Pareto- Optimisation, Techno-economical system, Coefficient of Performance, System design

Introduction

Addressing the common wrong assumption that systems can be optimised by optimising their components, we present a general analytic optimisation method on system layer. This method is applied to an energy system. The energy system involves the operation of wind-propelled vessels equipped with hydrokinetic turbines so that the kinetic energy of the water flow relative to the hydrokinetic turbine is converted into electricity. This electric power then is used to split sea water electrolytically into hydrogen and oxygen. The hydrogen gas then is compressed and stored in tanks. First conceptual studies of this energy system have been made by Platzer [1]. A more detail analysis has been performed by Pelz et al. [2]. The optimisation considers energetic and economic aspects simultaneously, whereby the optimal system in design and operation can be determined.

Analytic system optimisation in method and application

First the idea of a system needs to be stated as shown in the introduction. The next step is to describe the system based on a physical model. In our example the result of the description is the vessel speed as a function of physical parameters such as the resistance force of turbine and vessel and the thrust resulting from the aerodynamic lift. The next step considers the evaluation of the system characteristics of interest, in this case energy and economy. For the purpose of evaluation, reasonable system quantities needs to be defined. All these system quantities need to converge in an optimisation function. Figure 1 shows the energetic and economic flow through the energy system. They converge in the produced hydrogen which is a quantity for the energetic efficiency and the economical revenue. The energetic description of the system is applied by using the first law of thermodynamics. As the energetic system quantity, the coefficient of performance is defined as the ratio of the turbine and available power. The economic system description is supplied by the economic profit function. The economic system quantity is the yearly profit, which is the difference between the yearly revenue and the yearly costs. Using yearly costs the discounting of capital needs to be considered. The yearly revenue is proportional to the yearly produced mass flow of hydrogen. Therefore the revenue is a function of the energetic efficiency of the system. Through the revenue the energetic system quantity and the economic system quantity converge and generate in this way the optimisation function. In the next step the system is optimised by means of the objective function to maximize the yearly profit. This optimisation is performed analytically and provides optimal system design and operation parameters. The resulting Pareto- frontier includes all optimal systems, which cannot be improved energetically without simultaneously worsening them economically.

Conclusions

The analytic system optimisation provides the optimal dimensioning and operation of components in a system with a fixed component architecture. Therefore it is a strong tool to optimise the system design process because economical and technical aspects are similarly considered. Only the consideration of economic aspects leads to reasonable component dimensioning.

Acknowledgement: The authors would like to thank the Deutsche Forschungsgemeinschaft (DFG) for the financial support in the framework of the Excellence Initiative, Darmstadt Graduate School of Excellence Energy Science and Engineering (GSC 1070).

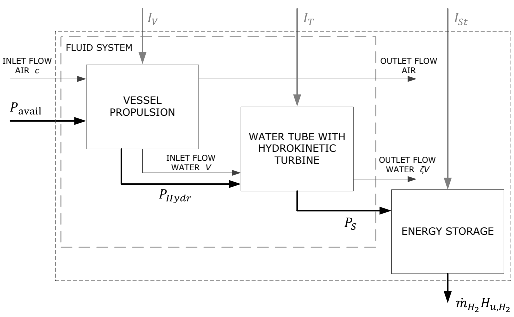

Figure 1: Block-diagram of the energy system

References:

[1] Platzer M, Sarigul-Klijn N, Young J, Ashraf M, Lai J; Renewable hydrogen production using sailing ships; ASME Journal of Energy Resources Technology 136; 2013

[2] Pelz P F, Holl M, Platzer M; Analytic method towards an optimal energetic and economical wind energy converter; submitted to Journal of Renewable Energy; 2014