A Comparison of Co-Simulation Interfaces between Trnsys and Simulink: A Thermal Engineering Case Study

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1. INTRODUCTION

Complex systems are usually decomposed into sub-systems, which are often modelled using different tools and methods. Co-simulation is a novel approach which aims at a cooperative simulation of several such tools. This paper presents a discussion of different co-simulation interfaces between Trnsys and Simulink. The interfaces are compared with respect to user-friendliness and flexibility, computational costs and accuracy. For this purpose, a thermal engineering case study is considered, which includes a compact thermal energy storage modelled in Trnsys and a heat sink modelled in Simulink. The interfaces considered include the Functional Mockup Interface (FMI), the Building Controls Virtual Test Bed (BCVTB) and a Component Object Model (COM), based on Trnsys' Type155.

2. CO-SIMULATION INTERFACES

FMI (Blochwitz et al., 2009) is a tool independent standard that has been developed in the ITEA2 European Advancement project MODELISAR. FMI supports both model exchange and co-simulation of dynamic models using a combination of xml-files and executables. FMI is currently supported by 95 tools and is used by various industries and universities. The available implementation of FMI between Trnsys and Simulink based on (Widl, 2015) and (Modelon, 2017) currently allows for a loose coupling scheme only.
BCVTB is a software environment developed at Lawrence Berkeley National Laboratory (Wetter, 2011). BCVTB is based on Ptolemy II, an open-source software framework supporting experimentation with actor-oriented design. BCVTB allows in general for a loose coupling scheme only.
Type155 is available in Trnsys' standard library, and establishes a communication between Trnsys and Matlab. In order to build a coupling between Trnsys and Simulink, a Matlab-script was developed to start and stop Simulink simulations at each iteration to ensure a strong coupling scheme, see (Engel et al., 2017a) and (Engel et al., 2017c).

3. METHOD

We introduce a case study where a sorption-based compact thermal energy storage is coupled thermally to a simple heat sink. The corresponding system design is shown in Figure 1. We discuss continuous time co-simulation only,

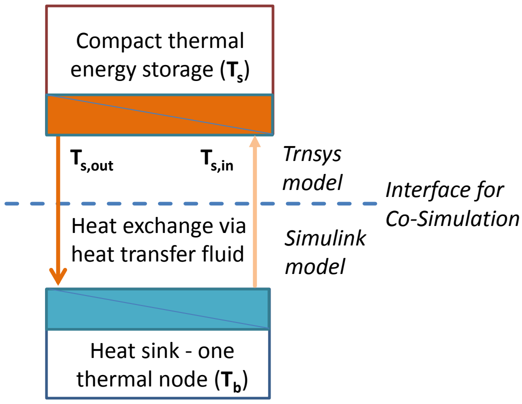

Fig. 1. The case study: A compact thermal energy storage is connected to a heat sink via a heat transfer fluid. The storage is modelled in Trnsys, while the heat sink is modelled in Simulink.

which is why discrete events like control switches are avoided. The compact thermal energy storage is modelled in Trnsys as detailed in (Engel et al. 2017b), results were presented also in (Engel et al., 2016). The heat sink including one thermal node is modelled in Simulink, as detailed in (Engel et al., 2017a).
The interface of the co-simulation is situated physically in the circuit of the heat transfer fluid. Correspondingly, the inlet and outlet temperatures $T_{\text{s,in}}$ and $T_{\text{s,out}}$ of the sorption reactor heat exchanger are the variables communicated via the interface between Trnsys and Simulink.
The different interfaces are compared with respect to user-friendliness and flexibility, accuracy and computational costs. The user-friendliness and the flexibility is judged only on a qualitative basis. The model is implemented also entirely in Trnsys, referred to as "reference simulation", employed with improved solver parameters to ensure high accuracy results. These serve for a discussion of the accuracy of the various co-simulations. The variables communicated via the co-simulation interface (inlet and outlet temperature of the heat transfer fluid) as well as the temperatures of the heat storage and the body are compared to the corresponding time-series results obtained in the reference simulation. The maximum deviation is considered as measure for the accuracy.

4. RESULTS

The behaviour trace of the system is shown as time series in Figure 2. The inaccuracies of the various interfaces are shown in Figures 3 and 4.

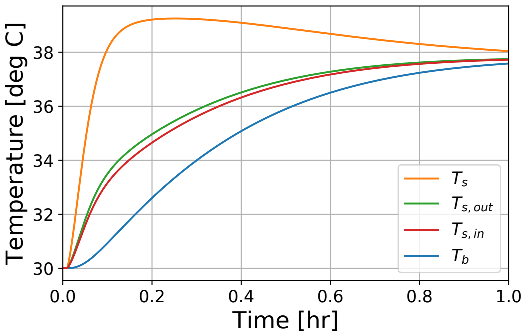

Fig. 2. Results for the temperatures of the heat sink T_b, the heat storage T_s, the outlet of the heat storage $T_{s,out}$ and the inlet of the heat storage $T_{s,in}$. The reaction increases the temperature of the heat storage up to roughly 39^{o}C, which is in the further progress cooled through the thermal coupling to the heat sink, until the different temperatures eventually converge.

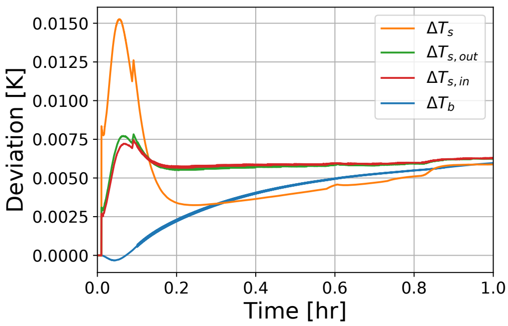

Fig. 3. Deviation of the different temperatures from the co-simulation based on the Type155 (strong coupling) compared to the ones of the reference simulation. The deviations of the monolithic simulation are in the same ballpark. For declaration of the variables see Figure 2.

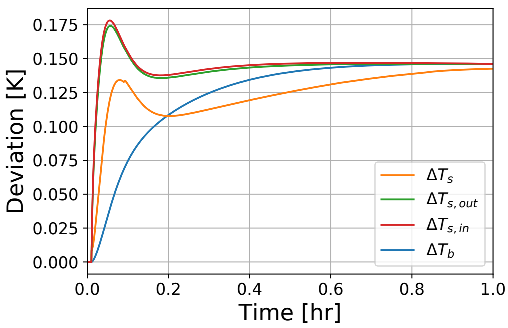

Fig. 4. Like Figure 3, but for the interface based on BCVTB or FMI (loose coupling).

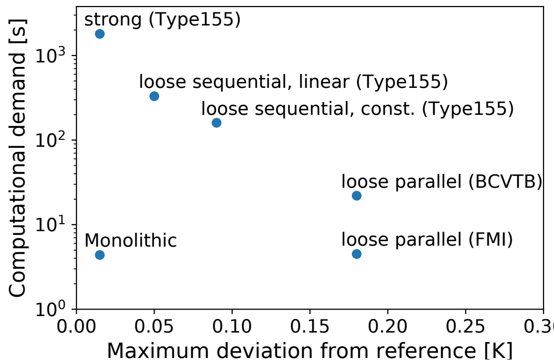

Fig. 5. An overview of different co-simulation interfaces, confronting accuracy and computational demand.

5. CONCLUSIONS

Considering the handling of the interface, the Type155-based interface offers a lot of flexibility to the user, allowing to implement loose and strong coupling co-simulation, and also various extrapolation schemes for the input variables. BCVTB offers out-of-the-box models for the various interfaces, while it is limited to loose coupling with a constant extrapolation of the input variables. FMI is a general and flexible approach, however, the implementation available specifically for Trnsys and Simulink is limited to loose coupling, due to restrictions imposed by Trnsys.
The accuracy and the computational demand of the implemented strong and loose coupling co-simulations differ significantly, as shown in Figure 5.

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