FACULTY OF ENGINEERING AND ARCHITECTURE

SUSTAINABLE THERMO-FLUID ENERGY SYSTEMS

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A CARNOT BATTERY TEST SET-UP CONSISTING OF AN ORC AND A HIGH TEMPERATURE LATENT HEAT THERMAL STORAGE

Introduction

ORC systems have extensively been investigated over the years. However, there is limited research in trying to understand the dynamic behaviour of ORC systems and reduce the effects of waste heat fluctuations on ORC system operation. A possible solution to this is the implementation of thermal energy storage (TES) systems to smooth the thermal power fluctuations entering the ORC system. At Ghent University Campus Kortrijk a 112 kWh latent heat thermal energy storage (LHTES) system is commissioned and integrated in a test-rig, consisting of a 250 kWe heater and a 11 kWe ORC, interconnected via a thermal oil circuit. This test-rig is used to demonstrate the advantage of a combined LHTES-ORC system enabling stable ORC operation under fluctuating waste heat conditions. Furthermore, it demonstrates the opportunities of the so called Carnot batteries in overcoming the mismatch between the energy supply and the power demand when generating electricity from renewable energy sources.

Experimental set-up

The LHTES (Fig. 3) with phase changing material melting at 222°C is part of a test rig, consisting of a 250 kWe heater and a 11 kWe ORC (Fig 2.), interconnected via a thermal oil circuit. The aim is to demonstrate that thermal energy storage enables stable ORC operation under fluctuating waste heat conditions and that it can bridge the mismatch between the non-dispatchable renewable energy supply and energy demand, acting as a so-called Carnot battery. The schematic of the experimental set-up is shown in Fig. 1. The LHTES can be charged by the electrical heater heating thermal oil (Therminol66) and discharged by a water cooled heat exchanger connected to a cooling loop. The LHTES has been implemented in a way both the ORC and LHTES can work simultaneously or independently.

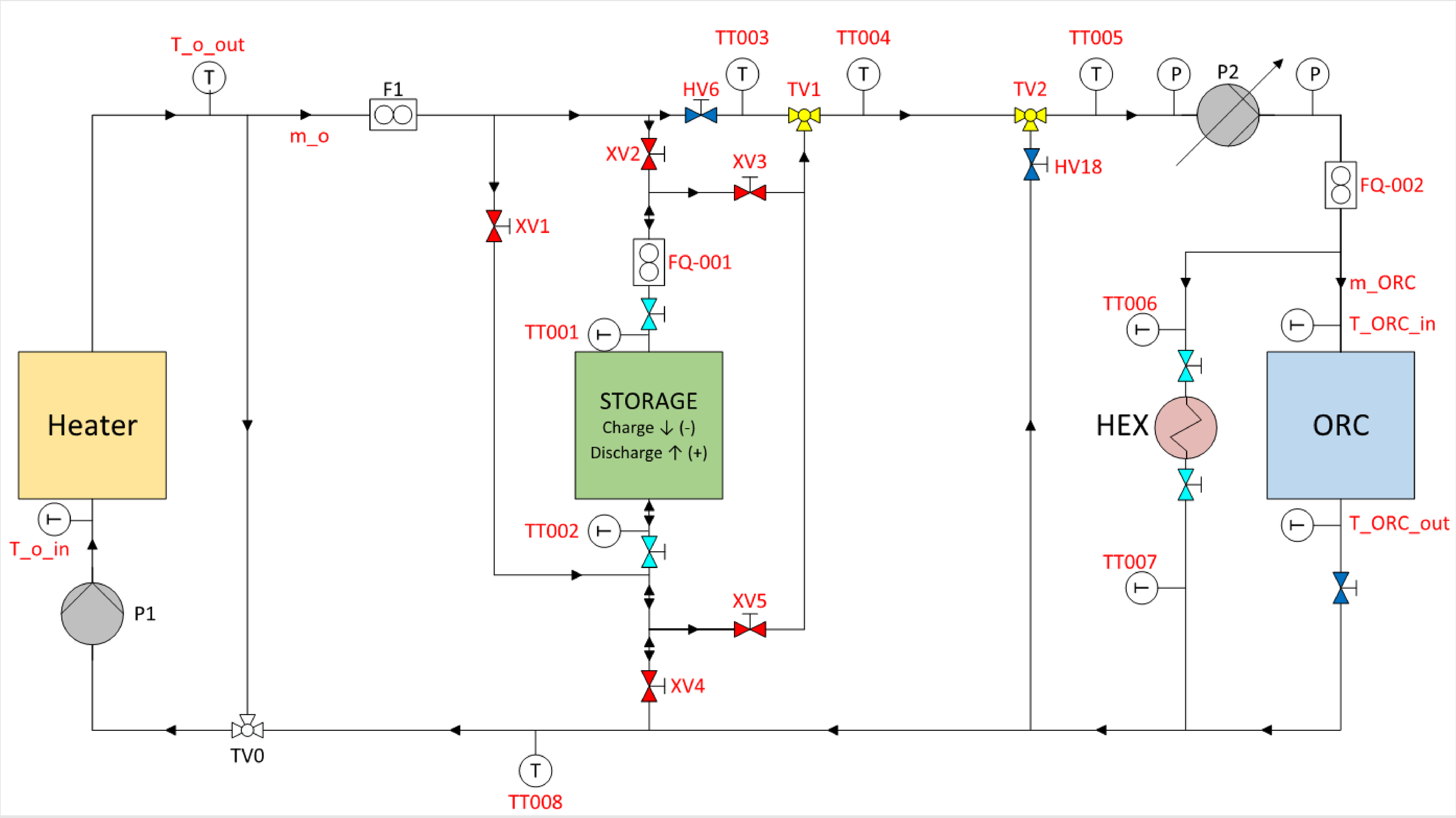

Figure 1. Schematic of the test set-up. Flow directions in the system are indicated by arrows. (Motorised) Globe valves are indicated as '(X)V', three way valves as 'TV', flow meters as 'F' and temperature measurements as 'T'.

Figure 2. Picture of the experimental 11 kWe ORC (campus Kortrijk Ghent University).

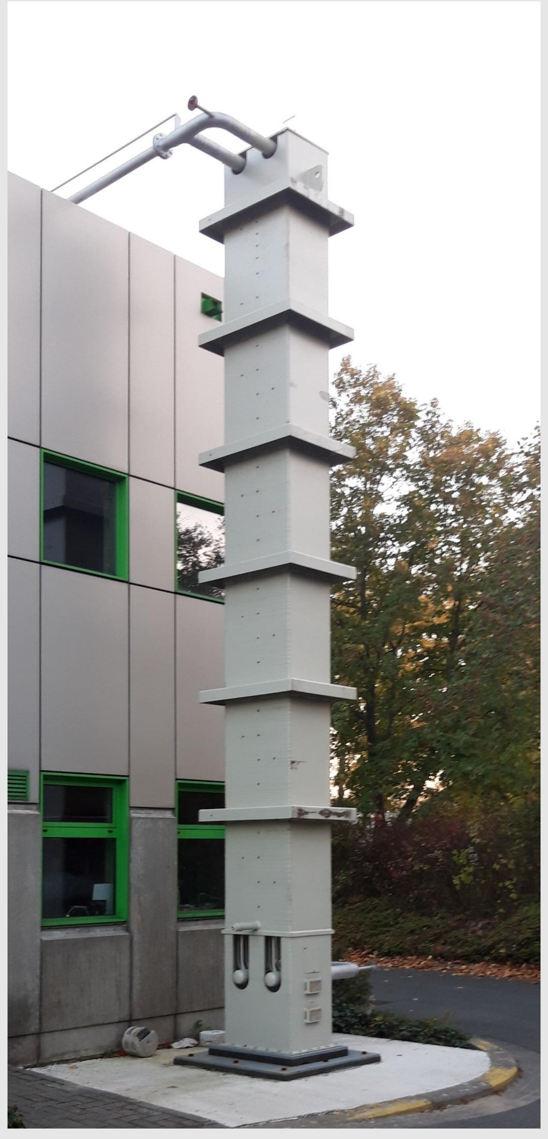

Figure 3. Picture of the installed shell and tube LHTES (campus Kortrijk Ghent University).

Experimental results

Characterization of the LHTES in terms of charging and discharging behavior has been completed (Fig 4.) and the 11 kWe ORC has been made fully operational.

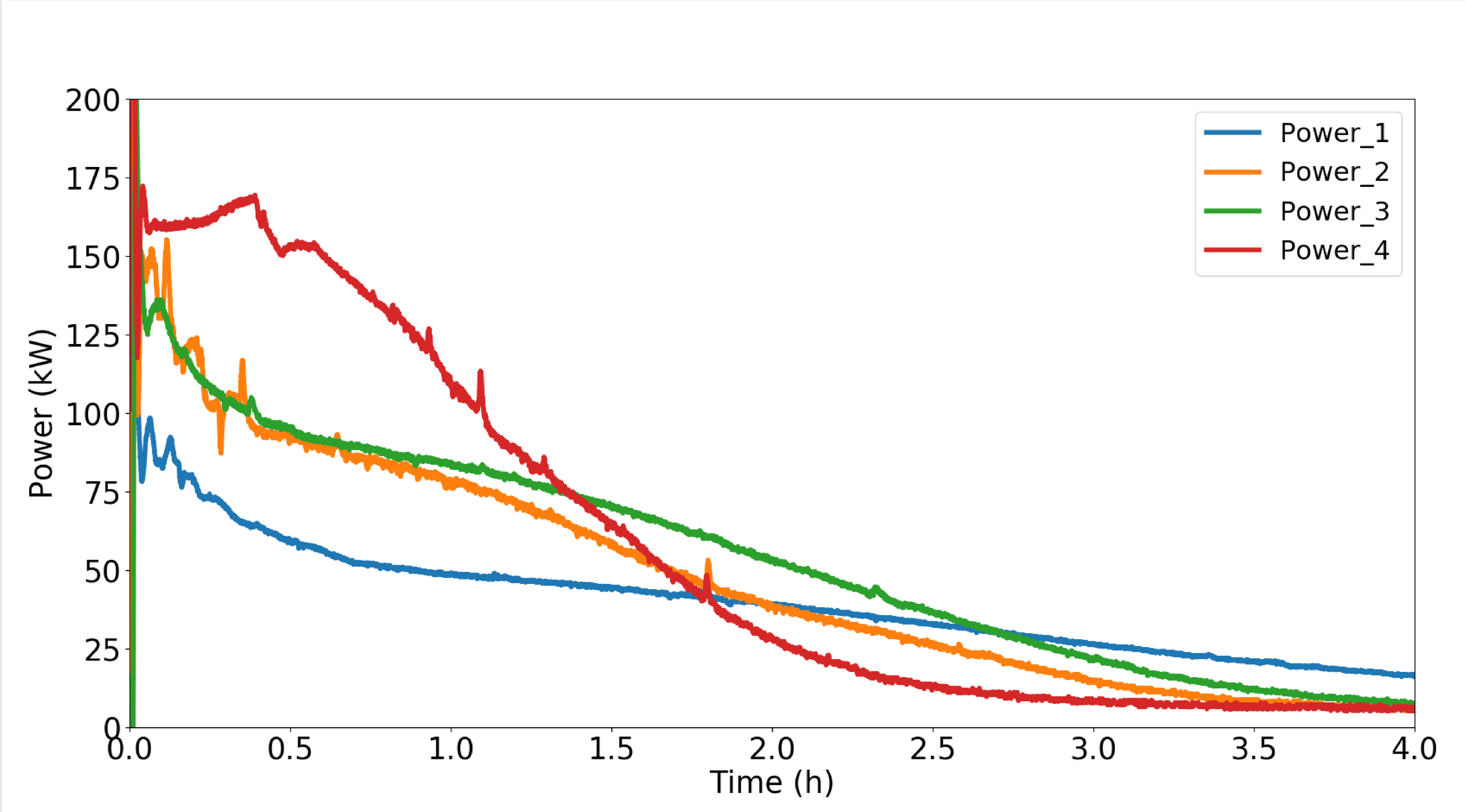

Figure 4. Experimental charging behavior of the LHTES under four different inlet conditions.

Modelling

Mathematical simulations of the finned shell and tube LHS are performed with a dynamic 2D model in Python based on the apparent heat capacity method and has been validated against experimental data (Fig. 5). For the ORC a steady state model is available predicting the power output in function of the heat source temperature and mass flow rate.

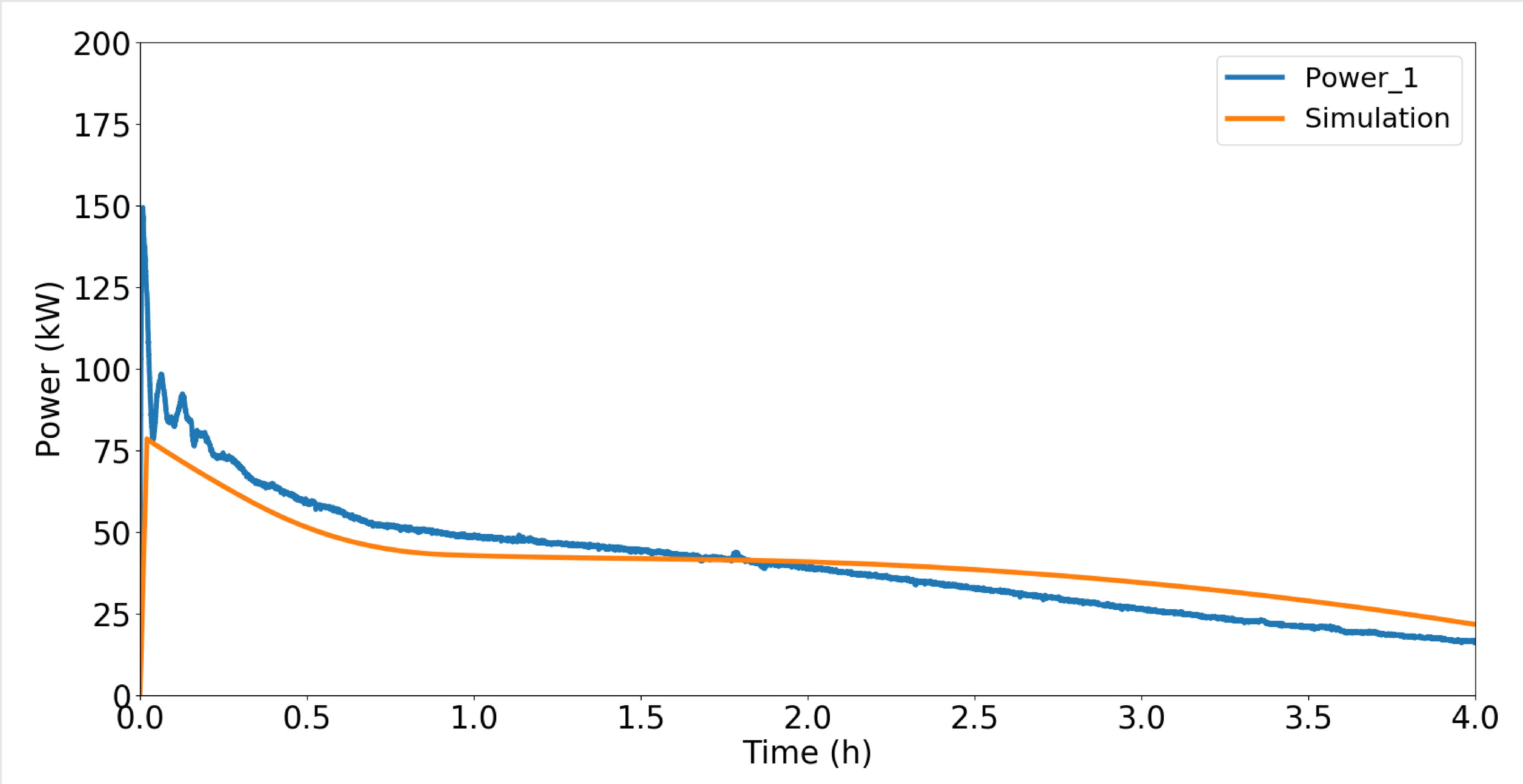

Figure 5. Comparison of the developed model simulation with experimental data.

Outlook

Based on the experimental characterization of the LHTES and the ORC system a performant control procedure will be developed to enable stable ORC operation. This means the heater output will follow a predetermined fluctuating heat source profile. These fluctuations will be automatically mitigated by charging or discharging the LHTES without disrupting the ORC operation. Both available models will be coupled to dynamically simulate the behavior of the combined LHTES-ORC system and validate with the experimental data. This model can then serve as an optimization tool to gain insight in the coupled LHTES-ORC system behavior.

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