Design of an experimental prototype of a solar-driven CCGT plant with thermal storage based on an existent solar power tower facility

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1. Introduction

In order to validate an approach to increase the flexibility of small scale tower power plants, within the project 'POLYPHEM' [1] a prototype combined cycle plant of 60 kW_{el} with a thermal storage (TES) of 1300 kWh [2] has been designed and will be built and installed on the site of the experimental solar tower of Themis in Targasonne (Fig.1, left). The concept consists of a solar-driven air Brayton cycle as top cycle and an Organic Rankine Cycle (ORC) as bottom cycle, linked through a stratified thermal energy storage (Fig. 1, right). To integrate the sub-systems into the existing research facility and interconnect them, outlining the full solar-to-electric conversion chain, a system layout has been developed, which addresses a wide range of operation modes and thus offers various test capabilities.

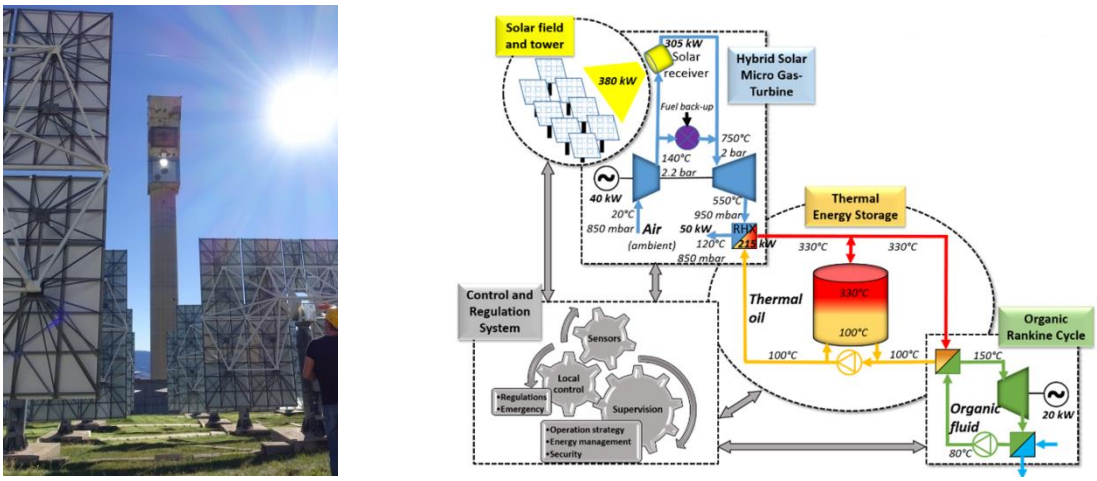

Fig. 1: View onto the tower at Themis - the installation site of the prototype (l); initial concept (r)

2. Methods / Approach

To identify the most suitable plant layout for the prototype at Themis with respect to future applications featuring diverging boundary conditions (e.g. smaller tower & solar field) the system was modelled and analyzed with a thermodynamic tool adopting simplified models of the sub-systems: solar receiver, gas-turbine (GT), TES and ORC. A technical assessment delivered the operating range of the system.

3. Findings

The analysis of different possible designs resulted in the final system layout with two oil-cycles decoupling the GT and the recovery heat exchanger (RHX) at the top of the tower with the TES and ORC at the base of the tower. Furthermore, all plant operation modes and transient states have been determined in order to cover a wide range of prospective commercial applications. Considering the allocated budget for the experimental

set-up the relevant features have been identified (e.g. solar driven GT, TES) which are to be tested experimentally, whilst other features of the system (e.g. power-to-heat-to-power) are intended to be investigated through simulation. Amongst the main outcomes of the work are heat and mass balances of the plant addressing the full spectrum of operation modes; Fig.2 illustrates the operation mode *Solar operation and storage charging*. The full paper will characterize all operation modes and the system in more detail.

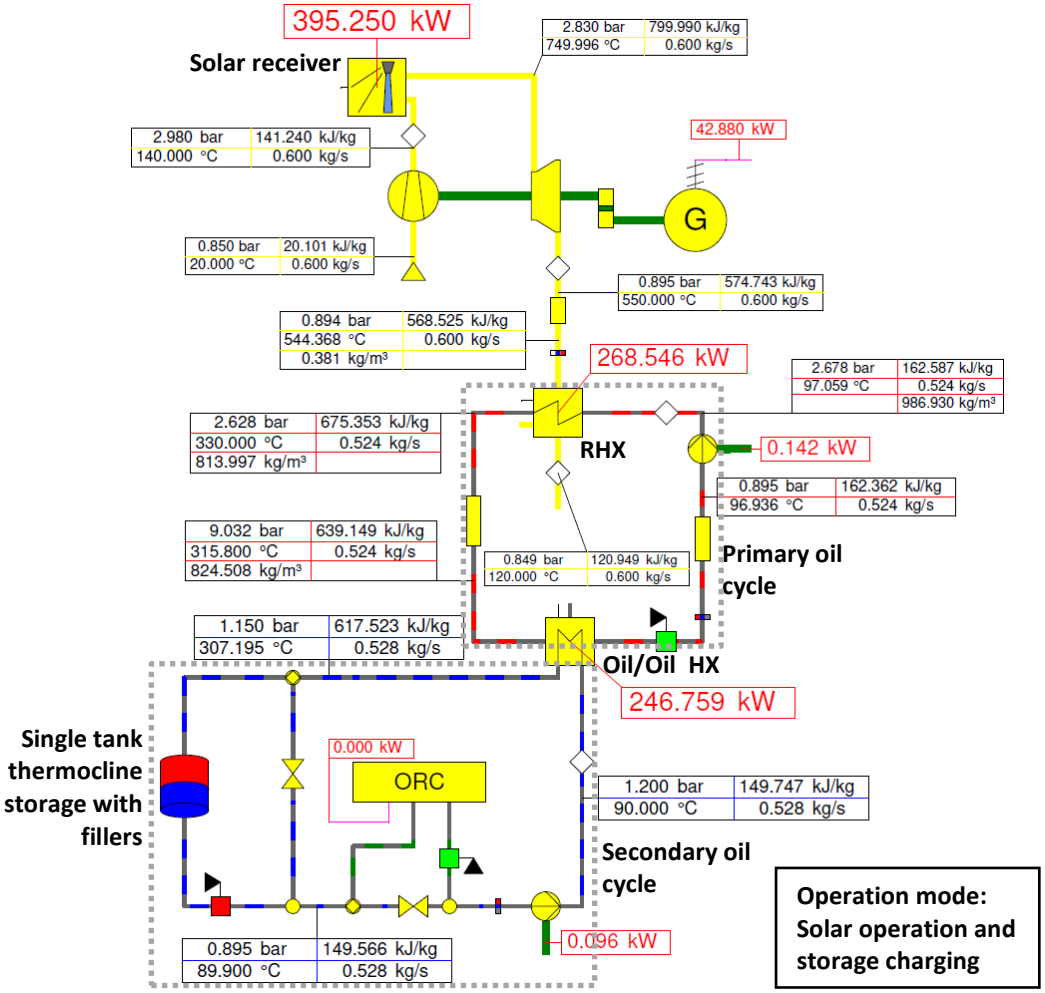

Fig. 2: Heat and mass diagram of the system modeled with EBSILON® Professional

4. Outlook and Acknowledgements

The elaborated results serve as basis for the detailed system design and control system. A profound simulation model for the system is under development. Eventually the complete system will be assembled 'on-site' and thoroughly tested under solar conditions, providing the opportunity to confirm the overall technical concept as well as to validate various simulation models.

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References

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