POLYPHEM
THE FUTURE OF SMALL-SCALE CSP PLANTS

POLYPHEM

Small-Scale Solar Thermal Combined Cycle

D7.1 Report on Preliminary System Modelling

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SUMMARY	*This document is the deliverable D7.1 of the project POLYPHEM. It is planned in the framework of the Work Package 7 (System Modelling and Performance Assessment).* *In this WP a dynamic simulation model of the overall plant is developed in several steps, where this report comprises the deliverable for Task 7.1. In this task a preliminary system model has been developed and implemented in the in-house simulation tool ColSim CSP by Fraunhofer ISE. Based on preliminary system components (not experimentally validated), the system is capable of simulation of 2 operation modes namely design mode and off-design mode.* *The current ColSim CSP model includes a detailed micro gas turbine model (compressor and gas turbine), heliostat field, solar receiver, the recovery heat exchanger, the primary oil loop, the black box ORC model, and the stratified storage.*
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List of Acronyms and Abbreviations

Acronym/abbreviation	Meaning/full text
AALB	Aalborg CSP
ARRA	Arraela S.L.
CA	Consortium Agreement
CEA	Commissariat à l'Energie Atomique
CFD	Computational fluid dynamics
CIEMAT	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas
CNRS	Centre National de la Recherche Scientifique
CO	Confidential: only for members of the consortium (including the Commission Services)
CSP	Concentrated Solar Power
D	Deliverable
DNI	Direct Normal Irradiance
DPM	Design point model
EU	European Union
EURO	Euronovia
FEM	Finite element method
FISE	Fraunhofer Institute for Solar Energy Systems, ISE
KAE	Kaefer Isoliertechnik GmbH
M	Month
µGT	Micro gas turbine
MS	Milestone
ODM	Off-design model
ORC	'Orcan Energy AG' or 'Organic Rankine Cycle'
PU	Public
RHX	Recovery heat exchanger
TES	Thermal energy storage
TIT	Turbine inlet temperature
VDI	Association of German Engineers (Verein Deutscher Ingenieure)
WP	Work Package

INTRODUCTION

The aim of the POLYPHEM project is to improve the flexibility and the performance of small-scale concentrated solar power (CSP) plants. This is achieved by a novel concept of integrating a solar-driven micro gas turbine with a secondary cycle including a thermal energy storage (TES) and an organic Rankine cycle (ORC).

This report summarizes the approach and results of the preliminary system modelling (Task 7.1) in the scope of WP7.

1.1 OBJECTIVES AND TASKS

In Task 7.1, a preliminary system model is developed by Fraunhofer ISE in the in-house software ColSim CSP, which integrates an optical ray tracing assessment of heliostat field and receiver based on the in-house software Raytrace3D. This preliminary system model forms the basis for the final system model and performance assessment which is the overall goal for WP7.

In a first step in Task 7.1, a detailed dynamic system model with preliminary component models is set up. This includes the following components:

- Compressor
- Cavity panel receiver
- Heliostat field (via ray tracing pre-calculations)
- Turbine
- Recovery heat exchanger
- Primary oil loop
- Secondary oil loop
- TES
- ORC
- Pipes and additional heat exchangers where needed

CONCLUSION

In WP7, a dynamic simulation model of the overall plant has been developed in several steps, where this report comprises the deliverable for Task 7.1. In this task, a preliminary system model has been developed and implemented in the in-house simulation tool ColSim CSP by Fraunhofer ISE. Based on preliminary system components (not experimentally validated yet), the system is capable of simulation of 2 operation modes namely design mode and off-design mode.

The current ColSim CSP model includes:

- A detailed micro gas turbine model which can simulate the behaviour of a micro-gas turbine / compressor set with constant rotational speed of 52000 rpm as well as the losses in the gear box and the generator;
- The heliostat field is simulated in detail using the in-house ray tracing tool and provides the system simulation software with an input file containing the annual concentration factors;
- A solar cavity receiver model based on an adapted panel model which allows for a flexible combination of different components such as tubes, panels, splitters, mixers or passive surfaces. The thermo-hydraulic receiver model makes use of transient flux maps on receiver surfaces and takes into account natural and forced convection in the cavity;
- An Air/oil heat exchanger for the RHX based on the design from AALBORG and a heat transfer coefficient from literature and a constant pressure loss;
- A simplified black box ORC model based on polynomials for output power and outlet oil temperature extracted from the simulation tool of ORCAN;
- and finally, an adapted version of the existing detailed model of stratified storage.

All the three loops of the plants are therefore implemented and integrated with a basic control strategy and the deliverable 7.1 is successfully completed.

Further development of the model is ongoing with following goals:

- Extension of the plant operator/controller based on the detailed definition of operational strategies, plant status, and the boundary conditions of the plant in WP4
- Inclusion of the pressure loss calculation in part-load operation of the RHX
- Including start-up and ramp-up procedures in the model
- Possibly simplification of the stratified storage model for reduced calculation time
- Possibly including a model for the combustion chamber of KAEFER
- Adaptation of the gas turbine model to variable speed model

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