The POLYPHEM Project: an Innovative Small-Scale Solar Thermal Combined Cycle

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1. Introduction

The POLYPHEM project is a Research and Innovation Action granted by the EU as part of the Horizon 2020 program. This project addresses the topic "Developing the next generation technologies of renewable electricity and heating/cooling". The main objective of POLYPHEM is to improve the flexibility and the performance of small-scale Concentrated Solar Power plants. The outcomes of the project will allow in the short term to reinforce the competitiveness of this new low carbon energy technology and therefore to favor its integration in the European energy mix.

POLYPHEM is carried out by 4 research centers CNRS-PROMES, CEA-LITEN, CIEMAT-PSA and FRAUNHOFER ISE, and 5 private companies ARRAELA SL, KAEFER Isoliertechnik, ORCAN Energy, EURONOVIA and AALBORG CSP.

2. Concept

The overall concept underpinning the project is to bridge together two thermodynamic cycles with an intermediate storage system to make a combined cycle with unique flexibility. Three innovative ideas bear the POLYPHEM concept:

- Coupling a small-scale organic Rankine cycle (ORC) with an open Brayton cycle (µGT) to make a novel combined cycle
- Integrating a high temperature solar receiver in the top cycle.
- Integrating a low cost thermal energy storage (TES) between both cycles

The resulting concept is a solar-driven combined cycle featuring a small-scale CSP plant of next generation. As it is illustrated by the sketch in Fig.1, five technology bricks are integrated to form the complete innovative system: the solar field and tower, the hybrid solar micro gas-turbine, the thermal energy storage system, the organic Rankine cycle and the control and regulation system. The power block is a solar power generation system able to meet the requirements of a local variable demand of energy with a high average conversion efficiency of 18% and a low environmental profile with an investment cost target below 5 €/W. Besides electricity generation, other applications will be considered for future developments, such as heating/cooling of multi-family buildings or water desalination for small communities.

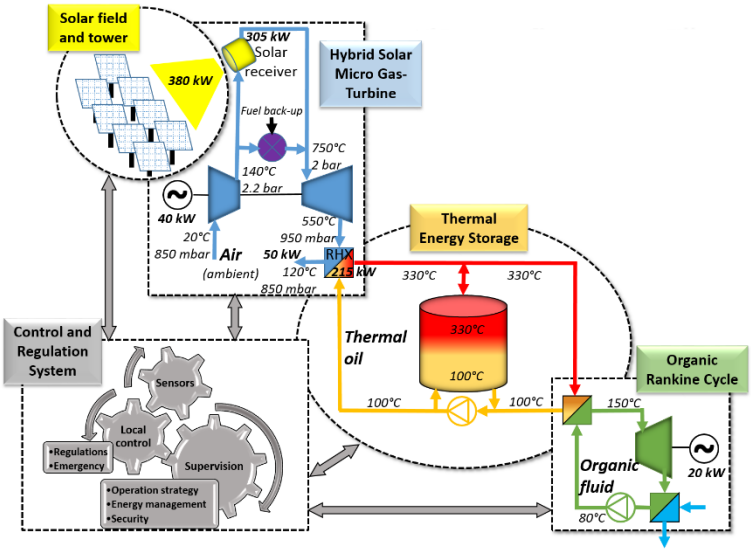

Fig. 1: The POLYPHEM overall concept

3. Advanced components

The concept of an efficient pressurized air solar absorber has been proposed and validated by CNRS and CEA at laboratory scale [1]. Under standard solar direct normal irradiance of 1000 W/m^2, a temperature increase of 610°C from 140°C at the inlet up to 750°C at the outlet is targeted with a pressure drop below 5%. The solar-driven micro-gas turbine (µGT) is the Garett GT30-67 engine. It is adapted for operation in solar-only mode or in hybrid solar mode. At least 80% of the heat contained in the gas at 550°C at the exhaust of the µGT is recovered and transferred to the HTF of the TES unit by the recovery heat exchanger. The temperature of the HTF is maintained at the set-point (typically 330°C) and the pressure drop in the gas flow is lower than 5%. The thermal storage system is a thermocline with a concrete single tank, a concrete filler and thermal oil as Heat Transfer Fluid (HTF). The development of this component is reported by Rojas et al. [2].

4. Experimental and modelling

The project will build a 60 kW prototype plant with a 2 MWh thermal storage unit and will validate this innovative power cycle in a relevant environment (TRL 5), assess its technical, economic and environmental performances and establish the guidelines for its commercial deployment. POLYPHEM will lead to a supply price of electricity of 21 c€/kWh under DNI of 2050 kWh/m2/year.

References

[1] B. Grange, A. Ferriere, D. Bellard, M. Vrinat, R. Couturier, F. Pra, Y. Fan, Thermal performances of a high temperature air solar absorber based on compact heat exchanger technology, ASME Journal of Solar Energy Engineering, Vol. 133, ISSN 0199-6231 (2011).

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