R&D on Thermal Storage in Polyphem Project

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1. Introduction

POLYPHEM project (Small-Scale Solar Thermal Combined Cycle) is a just born EU funded project where 9 entities (4 research organizations -CNRS, CEA, CIEMAT and FISE- and 5 industrial partners –Arraela, KAEFER Isoliertechnik, ORCAN ENERGY, AALBORG CSP and EURONOVIA) joint forces to develop a new technology based on the use of two thermodynamic cycles operated in the configuration of a solar-driven combined cycle with integrated thermal energy storage. This technology is intended to be used for decentralized small-scale power generation in remote areas within the range 40 kW to 2000 kW.

This paper will present the R&D activities planned to be performed in the project, analyzing the influence that such research will have in the STE community not only in the focused plant size of the project but also in large scale STE plants.

2. POLYPHEM project overview

The baseline technology consists of an air Brayton cycle as top cycle and an Organic Rankine Cycle (ORC) as bottom cycle. POLYPHEM broadens this technology by driving the top cycle with solar energy through the development of an advanced technology of pressurized air solar receiver and by including an innovative thermal energy storage unit (TES) between both cycles, as it is illustrated in Fig.1. Renewable electricity is generated by both engines in a highly flexible mode. 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.

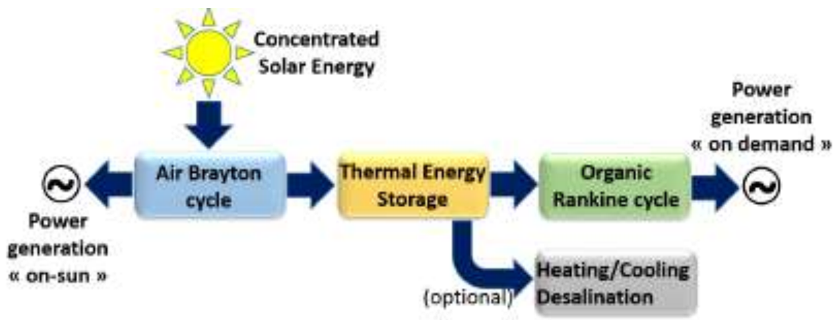

Fig. 1: Scheme of Polyphem's approach.

The POLYPHEM project will implement a prototype system and validate this innovative configuration for power generation in a relevant environment (TRL 5). It will assess technical, economic and environmental performances and establish the guidelines for the commercial deployment of this technology in the long term.

3. Thermal Energy Storage System

According to the Electric Power Research Institute (EPRI) the cost of the present molten salt two-tank system can be reduced to its 70% if using a single tank (thermocline) or even to its 33% if, additionally, the liquid storage medium is partially substituted by a solid filler (dual media thermocline) [1]. Thermocline TES systems, with and without filler, have been extensively studied both at modelling, [2] and experimental levels. Since the outcomes show that cost effective solutions are expected providing that careful design of tank and filler material is proposed, in POLYPHEM project a thermocline system with a solid filler will be developed. The first challenges to be addressed in this project are those dealing with avoiding the problems of thermal ratcheting by using a tank made of concrete and by studying its coupling with the solid filler. The use of concrete walls is also a solution to decrease the cost of conventional two tank system configuration just enlarging the affordable size of each tank. Big and/or hot tanks bring the problem of adequately insulating the foundations. Nowadays, a matrix of mineral porous pebbles is located between the tank floor and its foundations. These porous pebbles may break under the weight load of a large tank, losing their thermal insulating capacity and the required structural support for the tank base. In this project, foundations made of insulating concrete will be explored. In the POLYPHEM prototype plant, a 2 MWh thermal storage system will be erected in order to validate the results or the above mentioned studies. The extended utilization of concrete as filler, walls and foundations material is expected to reduce the TES cost in future installations. For small-scale STE plants the cost target for this storage technology is 28 €/kWh. The work package on R&D on Thermal Storage is organized according to the following paragraphs.

3.1. Studies on fillers

Comparison between different types of filler materials will be performed by studying their compatibility with the liquid storage medium, structural behaviour and their influence on thermal ratcheting. The agreed procedures for testing the filler as storage medium will contribute to other R&D initiatives, not directly linked to the project.

3.2 Lab-test of thermocline tank

The selected filler material will be primary tested using the in-house Microsol-R solar test loop at CNRS/PROMES premises.

3.3. Modelling and design of thermal energy storage system

In this task a unique reference model able to describe in detail the thermal performance of a thermocline tank with filler at both prototype and preindustrial scale will be proposed. The benefits of the vast models available, mainly of those of the partners involved, will be considered in this reference model. The required modelling issues for integrating the thermal storage system in the whole POLYPHEM plant approach will be also dealt in this task.

3.4 Tank design

The optimization of the concrete formulation for the tank is one of the main objectives of this task. The tank to be implemented in the POLYPHEM prototype plant will be designed here in terms of size and the required instrumentation for its testing identified.

3.4 Tank foundations

Foundations made of a special insulating concrete will be here proposed, considering that they have to be applicable for storage tanks larger than the current commercial ones. A comparison with the current solution for foundations using expanded clay Arlita® Leca® will be performed, both in terms of their effective thermal conductivity and mechanical behaviour under different pressure loads.

(Some) References

[1] Electric Power Research Institute, (2010), Solar Thermocline Storage Systems: Preliminary Design Study, Palo Alto, CA 1019581.

[2] M. Biencinto; R. Bayón; E. Rojas; L. González, (2014), "Simulation and assessment of operation strategies for solar thermal power plants with a thermocline storage tank", Solar Energy, 103, 456- 472.