The Role of Small-Scale CSP Plants in Future Energy Market

Case Study: A Solar Tower Driven Combined GT and ORC with TES

Nicholas Chandler[1], Shahab Rohani[2] and Thomas Fluri[2]

[1] M.Sc. Researcher; Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstr. 2, 79110 Freiburg, Germany

phone: +49 761 4588 5969, email: nicholas.chandler@ise.fraunhofer.de

[2] Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstr. 2, 79110 Freiburg, Germany

1. Introduction

Decentralized solar power plants are a promising solution to provide heat and electricity, especially for remote locations with no access to wide area synchronous grids. The thermal energy storage (TES) of concentrating solar power (CSP) technology is currently a feasible storage solution that can ensure dispatchable delivery of power through sustainable energy resources. Moreover, unlike photovoltaic plants with a battery energy storage system (PV+BESS) or wind energy technologies, CSP can be a direct provider of industrial heat at a range of temperature levels for various applications. It can also be configured as a combined heat and power (CHP) plant and/or a multi-objective plant providing drinking water through desalination.

The aim of this study is to technically and economically evaluate the performance of a small-scale CSP plant, identify the most relevant improvements necessary for such a system and develop a roadmap to bring small-scale CSP projects to market.

2. Methodology

For this study, an innovative reference small-scale combined CSP plant configuration based on a central receiver system is considered. This concept has been recently developed within the European R&D project POLYPHEM, where the primary aim of the project is to provide electricity and heat in isolated environments. The POLYPHEM plant uses an atmospheric air receiver as the heat source for the micro gas turbine. The exhaust gas is then cooled down in a recovery heat exchanger, specifically designed to heat up a heat transfer media which then runs an ORC unit at the bottom cycle and/or is stored in a single-tank stratified TES. A detailed description of the system can be referred to in [1].

This paper provides the results of a technical and financial benchmarking study that compared POLYPHEM against competing technologies in two locations: a small town in Namibia and a remote mining area in Chile. The competing technologies assumed are two common solutions for microgrids: PV+BESS and diesel generation via a generator. Additionally, grid expansion was also considered.

2.1. Techno-Economic Assumptions

The generation of the PV+BESS system per location is determined using Fraunhofer ISE's inhouse simulation tool ColSimCSP. The PV model is assumed to be fixed axis and the installed cost of the PV is assumed to be country dependent. The PV module used is the PV STP330x24 and the PV inverter used is the Renergy RS-5000 [240V]. The installed cost assumptions of the PV system in kW_{AC} were revised accordingly. The PV-BESS system is sized and optimized per location so that its annual yield and night-time BESS generation are equivalent to the CSP system.

Table 1: PV Installation Costs [2]

Location	1.2 DC-AC Ratio	1.9 DC-AC Ratio
Chile	1047 $/kW_{AC}$	1657.8 $/kW_{AC}$

Two types of commonly found batteries were considered: a lead-acid battery and a lithium-ion battery. The lead acid battery has a lifetime of 9 years and costs of approximately 147 $/kWh while the lithium-ion battery has a lifetime of 13 years and costs approximately 578 $/kWh [2]. Even though the lead-acid battery is significantly cheaper, the depth of discharge and energy density of the lead-acid battery are lower than the lithium-ion battery. Assumptions regarding the POLYPHEM plant, the diesel generator, and the grid expansion will be described in detail in the full paper.

3. Results

3.1. Case study 1: Antofagasta, Chile

The cost effectiveness of each system is strongly dependent on a variety of factors. For example, of the competing technologies considered, the diesel generator is the most expensive solution due to the high cost and consumption of diesel. As seen in Figure 1, with inflation maintained at 2%, the cost of diesel would have to be below 20 c$/liter. Another significant factor is that, in this scenario, the diesel generator will generate some 7153 tons of CO_2 over the 30-year period. Alternatively, as seen in Figure 2, a grid expansion is also expensive. The sensitivity analysis shows that grid electricity prices would have to decrease some 30-40% from the assumed 16 c$/kWh to make grid expansion economically comparable to POLYPHEM.

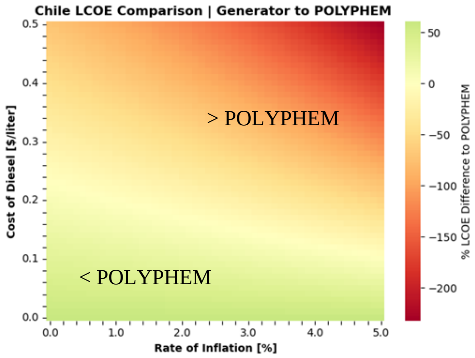

Figure 1: Diesel Generator Cost Sensitivity Analysis

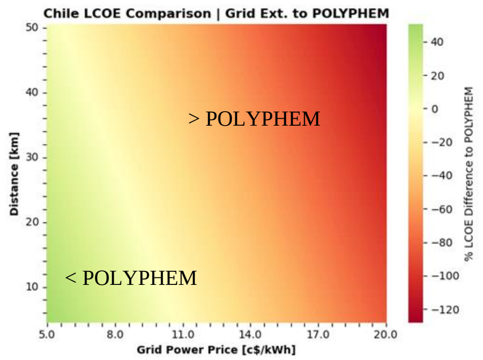

Figure 2: Grid Extension Cost Sensitivity Analysis

When the competitive LCOE's of the CSP and PV+BESS are compared, areas which have a high overall impact such as the performance of CSP components or future Lithium-Ion BESS costs are further investigated. The details of the benchmarking study, which include a sensitivity analysis performed on all four systems, and the concluding results of the analysis for the Namibia reference location will be presented in the full paper.

4. Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 764048.

References

1. A. Ferriere, S. Chomette, E. Rojas, J.-M. Caruncho, T. Fluri, D. Ipse, R. Aumann, M. Prouteau, and J. J. Falsig, "The POLYPHEM project: An innovative small-scale solar thermal combined cycle," in *AIP Conference Proceedings 2126 (2019)* , p. 30022.

2. IRENA 2020, Renewable Power Generation Costs in 2019 ISBN 978-92-9260-244-4 (2020).