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TEST BENCH FOR THE STUDY OF THE INTEGRATION OF CONCENTRATED SOLAR SYSTEMS IN INDUSTRIAL PROCESSES

Summary

The decarbonization of the industrial sector requires efficient solutions for renewable heat supply in medium-temperature processes (150–400 °C), where current deployment of solar heat for industrial processes (SHIP) remains limited. The Solar Thermal Energy for the Industry: Advanced Integration and Validation at Lab (STEILAB) project strives to achieve this by integrating concentrating solar energy with industrial processes. The main objective is to demonstrate the potential of solar thermal technologies to meet various industrial heat demands through the development and experimental validation of a pilot-scale test rig. The facility will be installed in Las Rozas (Madrid), taking advantage of a site with favorable solar conditions and direct access to laboratory infrastructure for instrumentation, control, and experimental analysis. The proposed system, with a target thermal power of 50 kWth, will employ linear Fresnel collectors (LFC), a mature and cost-effective technology capable of producing steam at temperatures above 150 ºC, and a Phase Change Material (PCM) Thermal Energy Storage (TES). After commissioning, the experimental characterization will be carried out to validate models and evaluate system performance under different industrial operating scenarios. This work presents the detailed design of the test rig and represents a key step toward the effective integration of solar thermal energy in decarbonized industrial processes.

Keywords: Solar Energy, SHIP, Linear Fresnel Collector

Field of application for the findings: Solar Heat for Industrial Processes

Addressed audience:

1. Introduction

The use of solar heat for industrial processes (SHIP) is a proposal for the use of renewable energy in industry (Kalogirou, 2003) that is gaining increasing relevance due to the decarbonization scenario and the decrease in its costs (a 43% reduction between 2014 and 2020 (IRENA, 2022). However, when analyzing the installed plants, the figures remain very low, with only 891 plants reported (AEE INTEC, 2024). Among these, most use non-concentrating solar collector technologies without tracking, which are easy to install to meet low-temperature demands (<150 °C), but cannot provide heat at medium (150–400 °C) or high (>400 °C) temperatures. Therefore, they cover only a small portion of the total range of industrial processes.

Solar collectors with concentration and tracking are mature technologies capable of reaching temperatures above 150 °C. There are various projects, both research and development as well as commercial, in which this type of solar collector is introduced into industry—particularly linear concentrating technologies such as parabolic trough collectors (PTC) and linear Fresnel collectors (LFC), whose costs can be competitive and whose target temperature range (150–400 °C) can cover a wide variety of industrial processes. The main challenges of these technologies are land requirements and energy dispatchability.

Recently, there has been intense research activity on the integration of different renewable sources for the decarbonization of the industrial sector, including concentrating solar power, together with thermal energy storage (TES) and high-temperature heat pumps (HT-HP). When working jointly, these technologies reduce the relevance of land limitations and ease the challenges of intensive electrification. The introduction of these systems has not yet been achieved at the commercial level, but it represents a promising solution compared to the current state of the art.

The main objective of the project "Solar Thermal Energy for Industry: Advanced Integration and Laboratory Validation" (STEILAB) is to contribute, through on-sun experimental demonstration, to an efficient and widespread supply of concentrated solar energy in integrated systems for a broad range of medium-temperature industrial processes and scenarios (150–400 °C), addressing current technological limitations. It uniquely combines pilot-scale linear Fresnel collectors with a controllable thermal load and phase-change thermal energy storage (TES) to experimentally validate integrated SHIP solutions under representative industrial conditions. In particular, the project aims to (i) analyze industrial scenarios and requirements (with a focus on Spanish industries) and (ii) establish a valuable testing facility to emulate case studies, validate models, and provide experimental data.

2. STEILAB Test Bench

The laboratory test bench is being designed to meet the established requirements and emulate the heat demand of various industries while enabling integration of solar thermal energy integration. Although the equipment will be selected once the final design is completed, a schematic of the system is shown in Figure 1. The main components of the system are the solar field, a PCM thermal storage tank, a controllable air cooler to emulate different industrial thermal demands, pumps, valves, temperature and pressure sensors, flowmeters, an expansion vessel and an instrumentation and control system.

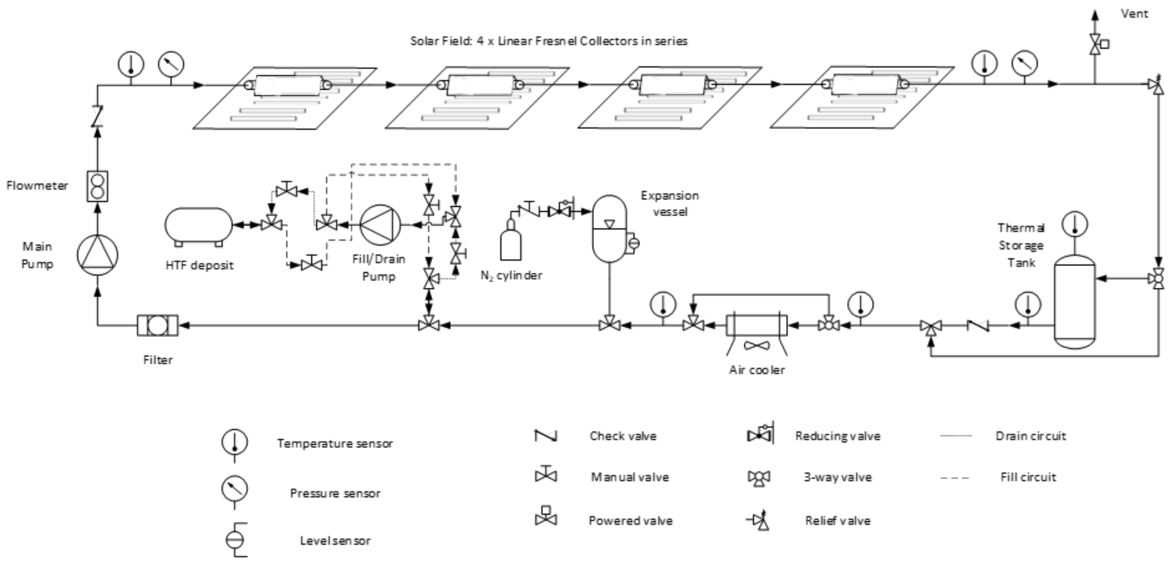

Fig. 1: Schematic of STEILAB experimental test rig.

The overarching objective of the test rig is to provide an experimental facility to evaluate the capacity of the concentrated solar thermal system, in combination with the novel thermal energy system briefly detailed below, to provide a stable source of heat to the simulated heat load at different temperature and capacity requirements.

In the proposed on-sun solar thermal experimental test-rig, two critical sub-systems, namely the solar field and thermal energy storage, will be comprised of pre-existing components that will be reutilised without major changes to their original designs. In other words, these reused collectors and a TES tank will be experimentally characterized to define operating limits, determine their operational constraints, and ensure compatibility with pilot-scale testing.

2.1. Solar thermal field

In the STEILAB solar field, four SOLATOM LF-20 Linear Fresnel collectors (will be deployed, with 6 receiver tubes in total, connected in series, capable of delivering up to 50 kWth at peak solar irradiance. Compared to thermal oils, Syltherm 800 provides higher thermal stability and lower maintenance, while maintaining safe handling compared to pressurized water or gases. Its high-temperature stability (up to 400 °C), non-corrosive and low fouling potential make it an ideal candidate for such an experimental rig.

2.2. Thermal Energy Storage

The thermal energy storage system will utilise a single tank that is comprised of solar salt as the Phase Change Material (PCM) storage in the annular space of the tank with tubes running longitudinally through the tank, carrying the HTF inside them. The heat transfer between the PCM and the tubes is enhanced through extended surfaces (fins) that have been geometrically optimised. The design, construction and experimental characterisation of this novel TES concept were integral aspects of the ASTEP European research project (ASTEP, 2019) and, following the conclusion of the project in 2025, one of the tanks fabricated will be transported and reutilised in the STEILAB solar experimental rig to verify thermal performance and ensure compatibility with the LF-20 solar field and HTF operating conditions..

3. Conclusions

The STEILAB test bench provides a platform for studying the integration of solar thermal energy into medium-temperature industrial applications (150–400 °C). The detailed design of the test bench is presented in this study. Following commissioning, experimental characterization will provide validated data on thermal performance, operating limits, and integration strategies. The combination of linear Fresnel collectors, controllable thermal load, and phase-change TES enables assessment under industrial scenarios. Finally, experimental tests will be conducted for various case studies, providing preliminary performance evaluation and insights into system behavior.

4. Acknowledgments

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5. References

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