Liquid metals, materials and safety measures to progress to CSP 2.0

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1. Introduction

Concentrating solar power (CSP), in the meanwhile considered to be one of the best issues to provide load balancing to grids and to increase the share of variable renewable energy sources (VRES), is presently investigated worldwide with the focus on industrial applicability and extended application range.

The next step of CSP will follow the development line to reduce costs and to enhance grid value in order to compensate VRES influence on grid stability. Extending temperature requires and adequate the heat transfer fluid (HTF) and advanced materials at affordable prices for piping and receiver. Also industrial power conversion systems (PCS) are presently available from the shelf in the temperature range of ~650 °C where standard steels are at their upper application limit. The next step will consider Brayton cycle based PCS using s-CO2 achieving temperatures up to 750°C.

Several studies identified liquid sodium as the most adequate HTF, which was used early in the 80ties of the last century. However, an accident during maintenance stopped that promising evolution. Further, a chemical fire at VastSolar reveals the need for the general concept of safety based sodium CSP facilities for optimization of components as well as training and education.

2. Objectives

Based on our experiences with rather low sodium temperatures (up to 550°C) in the KASOLA (KArlsruhe SOdium Laboratory) facility and our three SOLTEC (SOdium Loop to TEst materials and Corrosion [4]) facilities (up to 950°C), as shown in Fig. 1, we are confident that preemptive safety provisions are necessary and can be realized by tolerable costs.

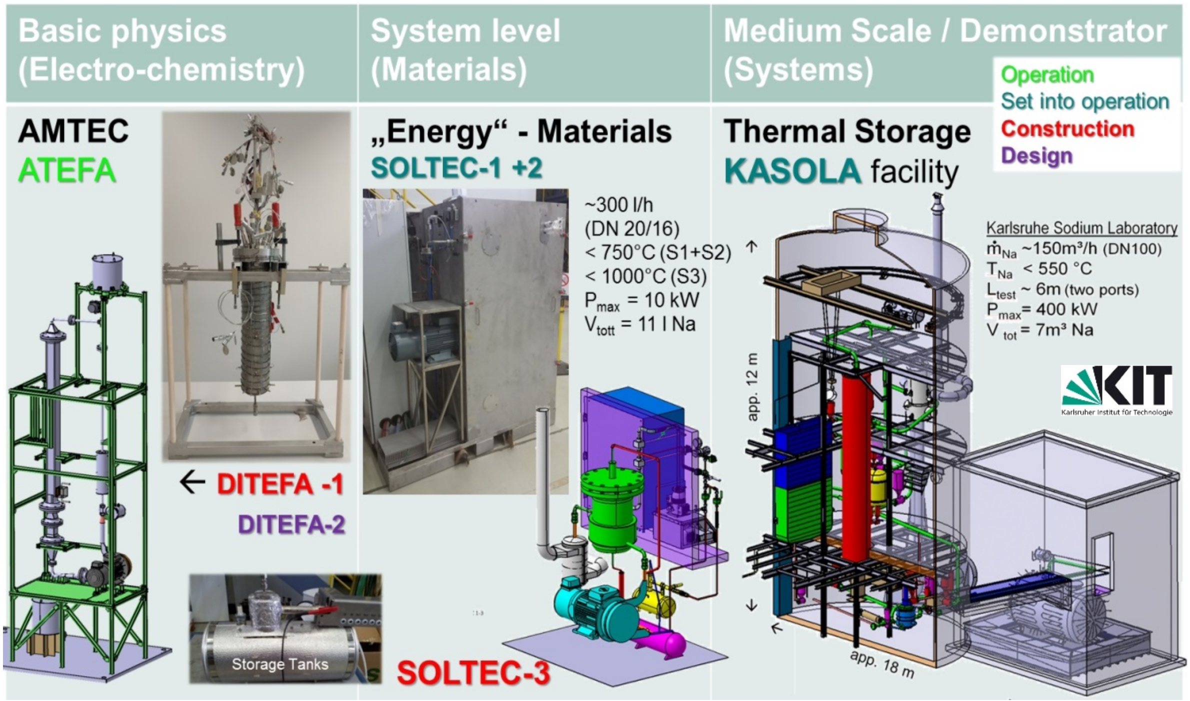

Fig. 1 Overview of KIT liquid metal facilities in the temperature range from room temperature to 1000°C

Especially the operating ATEFA facility [6] which allows sodium to be heated up to 1000°C for AMTEC (Alkali Metal Thermal Energy Convertor) was designed to be integrated in a standard laboratory. Based on our experiences a safety oriented design is an essential prerequisite for the success of sodium based solar tower power plants. The challenge is to optimize simultaneously competitiveness and safety.

3. Safety provision and mitigation for liquid sodium application

The talk will introduce the fleet of sodium experimental facilities at KArlsruhe SOdium Laboratory. Technical solutions for the safety challenges of sodium used in high temperature applications are presented and advanced materials, which are presently under development and investigation at KIT. Also, new ideas are presented to extend the temperature range [1], [2] as well as proposals for dual systems including a topping system based on AMTEC [3]. The paper describes the safety oriented design as realized in the KASOLA facility [4] and gives hints for scale up to industrial size systems, especially for temperatures up to 900°C [5], [6] including different thermal energy storage options [7]. Options for fast return to operation in case of failures are under discussion, to reduce HTF caused outages. The excellent heat transfer characteristic [2] and the required safety provision have to be taken into account to design receiver, heat exchanger and storage tanks. Finally, accident mitigation measures are discussed based on pre-emptive measures [8] including spreading of sodium aerosols taking credit from KIT's CDIM (Center of DIsaster Management) [9].

The project was funded in the frame of two Helmholtz activities: the Helmholtz alliance on LIquid Metal TECHnology (LIMTECH) and the Helmholtz Energy Material Characterization Platform (HEMCP).

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