Next-CSP

High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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Deliverable D 1.5

WP1 – Assessment of particle suspensions as heat transfer fluid and storage material

Deliverable D 1.5 Report on particle handling solutions for large-scale facilities

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Executive Summary

The Next-CSP project aims at developing a pilot-scale prototype (1.2 MW_{el}) of a combined cycle Concentrated Solar Power (CSP) plant using particles as a heat transfer and thermal storage medium. It also aims at leading the way towards commercial developments using this technology, by studying the scale-up to a commercial capacity of such a plant.
In the Next-CSP project, which will serve as the proof of concept at a moderate scale, particles are capturing heat in an Upflow Bubbling Fluidized Bed (UBFB) receiver with the concentrated solar flux coming from the heliostats. The hot particles will then be stored before heating a working fluid (air in the case of the Brayton power production cycle, and ultimately in a complete combined cycle power generation set-up). A fossil fuel boost is available to provide extra heat to the air feeding the gas turbine. The particles selected for the project are olivine (50-100 µm). The layout of the Next-CSP pilot project is illustrated in Figure 1.

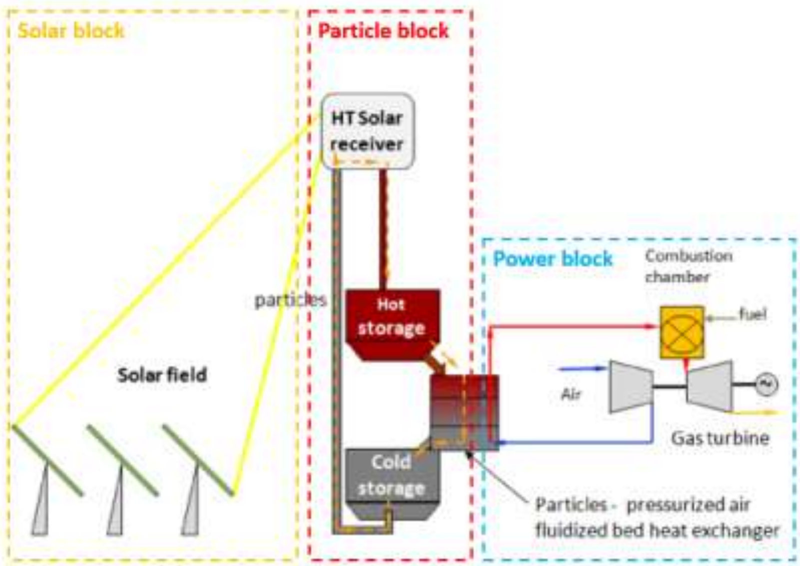

Figure 1 - Layout of a particle CSP plant

Cavity receivers are preferred for the envisaged layout, although for a 150 MW_{el} plant it will result in the use of multiple towers (see Deliverable 7.1). The total flow rate of particles through each receiver will be 164 kg/s (590 ton/hr). For the eight towers (receivers), 4723 ton/h of particles will need to be conveyed between towers and power block, and for the return circuit to the towers.

Because of the multi-tower configuration of the scaled-up plant and since its storage needs to be centralised near the power block for efficiency reasons, horizontal and vertical conveying between the towers and the storage hoppers will be needed.

Among the different systems studied, three were found especially promising for the horizontal or inclined part of the conveying: vibrating chutes (to evacuate particles gradually from receiver to further conveying, thereby limiting particle breakage and erosion), apron belt conveyors, and wagon systems. Although the wagons require less

power than the apron belt conveyors, they are more expensive, their loading/discharge stations and additional uplifting of the particles require moreover a higher integration in the plant than the apron belt conveyors which can readily dispatch powders towards high hoppers, fluidized beds in the power block, etc.
For short distances of horizontal conveying, at moderate conveying rate and for limited distances, high temperature screw conveyors could be envisaged.

To lift the powders from ground level to the level of the feeding hopper of the UBFB receiver, either bucket elevators, hoists, or a combination of bucket elevators and inclined apron belt conveyors is possible. Hoists are however slow and operate in a discontinuous manner hence imposing the installation of a huge buffer hopper atop the tower. The power required differs slightly from that required by the bucket elevators, being determined by the uplift power and the conveying efficiency. The use several buckets elevators in series and in parallel is preferred (their unitary maximum vertical uplift being limited at about 35 m and ≤ 300 ton/h).

Pneumatic Conveying systems are not taken into consideration, since they require a substantial amount of conveying air (≥ 1 kg air/10 kg particles) at a moderate to high pressure. Pneumatic conveying is moreover accompanied by huge heat losses, since the air will exhaust the pneumatic conveying at the particle temperature (between ~ 600 °C and 825 °C).

The Deliverable first introduces the different conveying systems for horizontal and vertical transport of the particles. Transport capacity and distance, operation temperature, acceptable elevation and consumed power (and heat losses) are considered. It thereafter makes a selection for both the Next-CSP process and a 150 MW_{el} full-scale combined cycle CSP project. For the latter, particle transport layout is proposed and parasitic power consumption is evaluated.