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Deliverable D5.1 - System configuration for thermocline concrete tank

ABSTRACT

The main objective of this deliverable was to provide to the consortium, namely to the operator of the tank, operating insights towards an optimized performance for the tank.

Developed models available in the literature and/or developed by LNEG/ETH and a new 2D model presented in this document were expected to be used as starting point to calculate the thermal performance and efficiency of the storage system.

LNEG used an own developed 1D model to evaluate the maximum and minimum mass flows proceeding from the solar field (boundaries for the charging stage) and the mass flow towards the power block (discharge stage), several filler porosities (this parameter includes the particle diameter definition), and H/D ratios. The effect of different parameters (such as, initial charging state or the position of thermocline gradient) was evaluated in the 1D model as well. The assessment of stand-by time was also discussed, as it will decrease the thermal stratification. In order to evaluate the tank performance with regard to the thermal losses, a typical daily charging/discharging cycle was defined (0h-8h: idle period; 8h-12h: charging period; 12h-16h: discharging period; and 16h-24h: idle period).

Considering that the system will not behave adiabatically, LNEG developed a new 2D model specifically for this problem geometry in order to study the proposed wall boundaries towards the heat losses assessment and their influence in the tank behavior. The detailed geometry allowed to perceive the temperature distribution inside the tank. 3 representative environment (external) conditions were considered as approximations in order to study the influence of heat transfer through the walls (Tair=20°C, Tair=30°C and Tair=40°C).

Mass flow rate

The mass flow rate ranged from 3,22 kg/s to 8,06 kg/s, yielding charging and discharging efficiencies between 89,7% and 90,7%, respectively, and 90,5% and 91,5%, also respectively. As a result, from the tests, the charging and discharging efficiencies increase with the increase in the mass flow rate.

Porosity

The porosity tests considered a local porosity (porosity means void space in the filler) ranging from 30% to 100%, equivalent to a global porosity of 54,2% to 100%, respectively (top and bottom buffer zones had no filler material). The yielded results showed that the charging efficiency decreases with local porosity and the discharge efficiency increase with local porosity.

H/D ratio

Several values H/D ratio were tested for both the charging and discharging periods, ranging from 0,92 to 1,80 for the charge period and 0,96 to 1,80 for the discharge period. The charging and discharging efficiency ranged from 89,6% to 90,7% in the charging period and from 90,6% to 91,7% in the discharging period.

Thermal diffusion

An idle period of 72h starting with the theoretical no thickness thermocline was tested, for local porosities of 30%, 40% and 50%. According to the 2nd law of thermodynamics, the thermocline thickness increases with time and storage efficiencies were found ranging from 76,4% to 78,8%, respectively.

Thermal losses

Considering the air temperatures of 20 °C and 40 °C and a wind velocity of 6 m/s, the global heat losses through the boundaries for a daily cycle (starting idle and isothermal at 180 °C) were calculated as 40,61 kWh and 36,97 kWh, yielding a thermal dissipation power of 1,69 kW and 1,54 kW, respectively. Variable porosity along the tank was also tested with identical results.

As a result of the simulations performed in the 1D model, LNEG successfully defined equations to foresee the thermocline performance as a function of mass flow rate, porosity and H/D ratio.