APPLICATION/CONCRETE PROJECT

A CSP plant operates similar to a conventional steam-electric power plant in which fuel has been replaced by concentrated solar radiation. It can employ different types of tracking mirror systems to focus the sunlight. An integrated heat storage allows for demand-driven electricity production independent of solar radiation, which fluctuates over the course of the day (Fig. 1). With increasing shares of variable renewable energy being fed into the energy systems, this kind of controllability is becoming a key parameter for energy production. Sunny countries will be able to use CSP to replace fossil fuels with solar thermal power, provide cost-effective base- and peak-load electricity, and stabilise their grids in the future.

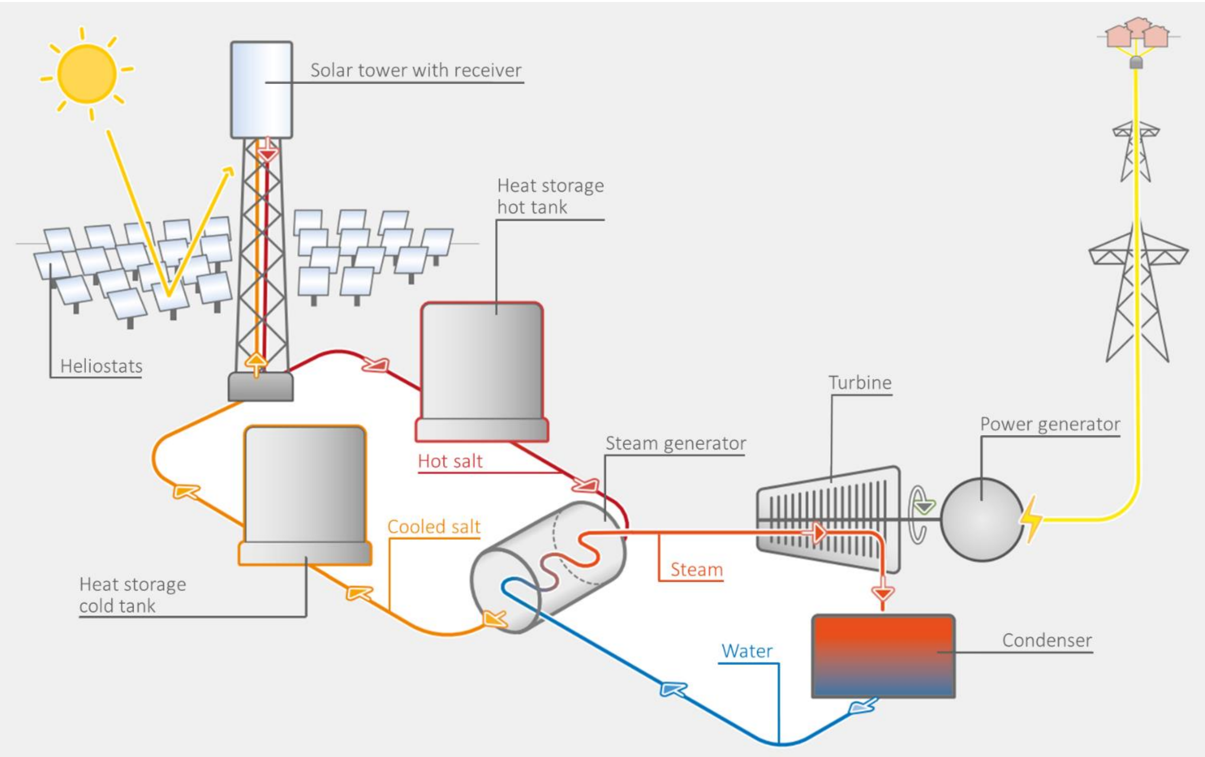

Figure 1: Functional principle of a CSP plant, shown here for a solar power tower (source: DLR)

Detailed description of storage application

Today, wind power and photovoltaic systems account for the largest ongoing increase in renewable electricity generation. However, their grid feed-in fluctuates with wind and solar irradiation. Currently, there are few solutions available for the profitable storage of large amounts of electricity to compensate for these fluctuations. Solar thermal power plants store heat, which currently costs about 80 to 90 percent less, instead of electricity. This way, they can generate solar electricity even when the sun is not shining.

Liquid salt storage technology saw its first large-scale implementation in the Spanish CSP plants Andasol 1-3, built with significant involvement of German company Flagsol. The first storage system, Andasol 1, has been in operation since 2008. The technology has thus been successfully demonstrated and operational experience can be drawn on.

Figure 2: Liquid salt storage in a CSP plant (source: Andasol 3)

Technical details of concrete product: Andasol 1

Operating experience: since 2008

Storage capacity: 1,010 MWh

Storage power: about 120 MW (6 heat exchangers)

Tank dimensions: 14 m high, 36 m circumference per tank

Storage duration: 7.5 hours

Total mass of salt: 28,500 tonnes (60 % sodium nitrate, 40 % potassium nitrate by weight)

Service life: over 20 years

Necessary resources/limiting factors in implementation of application example

The nitrate salts used in liquid salt storages can be obtained via synthetic routes (Haber-Bosch Process) or extraction from natural deposits (e.g. Atacama in South America). The supply of raw materials is no constraint.

Benefit for the user/customer

Liquid salt storages are used for demand-oriented electricity supply from solar thermal power plants. The technology has the potential to be transferred into new end uses (e.g. electricity storage or conversion of conventional power plants and industrial process heat, with or without cogeneration) and thus contributes to a successful energy transition.

This gives the customer the following concrete benefits

- ### Economic benefit

  Despite the additional investment necessary for a liquid salt storage, electricity generation costs less in a CSP plant with storage than in one without. For the Andasol plants, the cost with storage is about 10 % lower. This comes down to the setup's more constant load profile and consequently more predictable energy production. This reduces running cost while the gained temporal flexibility allows for taking advantage of price peaks in the market.

  #### Revenue structure: what are the detailed economic benefits?

  In all relevant countries where CSP plants were installed, political frameworks were established to generate secure long-term revenues from electricity feed-in (e.g. expansion targets, feed-in laws).

- ### Ecological benefit

  CSP plants provide purely renewable energy, while liquid salt storages stabilise their output and thereby help to replace fossil flexibility options, such as gas-fired turbines. Depending on the storage's size, these may be rendered partially or completely unnecessary.

- ### Pros and cons

  Compared to storages based on thermal oil, pressurised water, or solids, liquid salt storage technology offers the following benefits: low cost, non-flammability, easy scaling, high operating temperatures, and the ability to provide constant temperature and power levels during discharge. Also, liquid salt is suitable for, both, heat transfer and storage, so in some applications it eliminates the need for a heat exchanger.

  CSP is only viable for regions with many hours of direct sunlight. For other regions, it requires a transfer of the technology to new applications. In CSP, numerous technologies using alternative heat transfer media are currently under development. Presently, only a specific temperature range of about 170–560 °C can be covered by liquid salt storages. For other temperature ranges and heat transfer media, solid bed, latent heat, or thermochemical storage systems are more suitable.

Cost structure

The liquid salt used for storage accounts for a significant part of the investment. Other major cost factors are tanks, heat exchangers or steam generators, pumps, foundation, insulation and engineering, as well as the cost of construction and commissioning. Operating costs arise from maintenance, personnel, and the electricity consumption of pumps and auxiliary heating systems. Total storage cost typically ranges from 20–70 €/kWh_{th} at this time, depending on boundary conditions (e.g. storage size, temperature spread, output).

The payback period is usually calculated for the overall CSP plant. Its duration depends strongly on the given political framework (feed-in laws) and local conditions (e.g. solar irradiation, temperature, availability of cooling water). After a successful incubation of the markets, CSP technology is now in a phase of steep learning curves and significant cost reduction.

Which framework conditions are necessary to render the application example economically feasible?

Political framework conditions or feed-in laws are required to additionally reward the provision of base-load electricity and a demand-oriented provision of renewable energy. If liquid salt technology is to be successfully transferred into large-scale end-use applications (e.g. conventional power plants, process heat), the demand-oriented uptake (via power-to-heat) and provision of energy (via power generation) must be rewarded on the electricity market while hindrances to the provision of balancing energy must be removed.

Additional references

In 2018, 42 solar thermal power plants with liquid salt storage were in operation worldwide. Their combined storage capacity amounted to approximately 49 GWh_{th}. This corresponds to an electrical output of 3.1 GW_{el} and a storage capacity of 18.5 GWh_{el} in the grid.

For further information, see

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