SOLAR TOWERS USING ATMOSPHERIC AIR AS HEAT TRANSFER FLUID FOR LARGE-SCALE POWER GENERATION

LIMITS:

CSP Tower systems using air as HTF are potentially capable of higher working temperatures than the current commercial technologies based on parabolic trough systems and towers using molten salts as HTF. However, their industrial exploitation has been so far hindered by limitations in the materials used for the central receiver - a key component in the system - and by the lack of efficient very high temperature thermal energy storage solutions, which dictate the maximum working temperature and the in-service overall durability against failure from thermal cycling and thermal shocks.

CHALLENGES/TECHNOLOGICAL NEEDS:

- Improving the central receiver, and
- Possibly re-engineering the whole systems downstream to work longer and at much higher temperature, especially in the thermal storage compartment.

NEXTOWER ADVANCED MATERIALS SOLUTIONS AND ARCHITECTURES

- Improved durable monolithic ceramic materials for open volumetric receivers of CSP systems of different size
- New thermal energy storage system for very-high-temperature (> 600°C) based on liquid lead
- Innovative corrosion-creep resistant steels for high temperature thermal storage (> 600°)

EXPECTED IMPACT

- New material technologies for the CSP Market that will increase the appeal of air-based CSP tower systems in the energy market
- Enabling materials for more competitive CSP systems and power cycles
- CSP market open to new application areas

PARTNERS

ENEA, KTH, Politecnico di Torino, Ciemat PSA, University of Oxford, SANDVIK, beWARRANT, Certimac, LiqTech, R2M Solution, CALEF, Siltronix, EngiCer, UNE, walter tosto, ICAMCYL

FOR MORE INFORMATION:

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OPTIMIZED MATERIALS AND NEW THERMAL ENERGY STORAGE CONCEPT FOR MORE PERFORMING SOLAR POWER TOWER CSP SYSTEMS

THE CONTEXT:

CONCENTRATED SOLAR POWER TECHNOLOGIES

Concentrated solar power (CSP) is an important building block in installing a secure, competitive and sustainable energy system.

Today, the diverse solar thermal energy solutions commercially available differ with respect to concentration technology, receiver type and shape, nature of the heat transfer fluid (HTF) and capability to store thermal energy, to turn it later into process heat or electricity on demand.

However, more cost-effective solutions are required for a wider-scale deployment of the CSP technology.

Novel functional materials and material combinations throughout the manufacturing chain are therefore needed to enhance the efficiency of solar energy harvesting beyond that of the current state-of-the-art technologies.

NEXTOWER ENABLING SOLUTIONS

CERAMIC SOLAR RECEIVER

1 Innovative ceramic for high-temperature open volumetric receivers based on all-SiC honeycomb design by VPS for more durability to oxidation.

PROVIDED BENEFITS

- Better ceramics for high-temperature receivers - with extended durability (20-25 years) vs thermal fatigue and thermal shock
- Superior thermal properties and reliability
- All-SiC ceramic receivers optimized for oxidation:
  - Porosity of 30% in the cup
  - Porosity of 43% in the square part
  - Pore size of 24 µm
  - Strength of 100 MPa

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- Innovative ceramic for high-temperature open volumetric receivers based on more flexible multiparts Si-SiC 3D printed design for higher toughness, higher thermal conductivity, and more open design.
- Optimized joining technique with proven scalability based on two steps methodology (Si coat on SiSiC disk and Mo-Wrap joining).

PROVIDED BENEFITS

- Si-SiC ceramic lattices for solar receivers optimized for higher toughness and thermal conductivity:
  - Performance: higher air temperature by same radiation and flow
  - Lifetime: 25 years with an inlet air flow at 900°C at concentrated solar flux density of about 2 MW/m2 and maximum thermal gradient of 70 °C/cm
- Interfacial cracking of the receiver made of three pieces avoided.

3 Coating and surface treatments to improve thermomechanical properties and emissivity:

- For increased thermal conductivity and thermal shock resistance: introduction by CVI of highly thermal conductive aluminium nitride (AlN)
- For reduced emissivity:
  - innovative metal-oxide coating by sol-gel deposition
  - engineering surface roughness by micropatterning
  - engineering surface coatings filled with nanocavity by plasmonic technology based on nanoparticles

PROVIDED BENEFITS

Increased thermal conductivity and durability of porous SiC receivers and reduction of their emissivity (in order of magnitude of 20%) to boost performance at higher temperatures (900°C)

4 A proposal of amendment to the current standard on thermal diffusivity determination with the Laser Flash Method (LFA) has been drafted and submitted to the ISO Standardization Body. The objective is to propose to employ a single standard and only the LFA method to characterize the whole thermal behaviour of the ceramic materials under investigation, in terms of thermal diffusivity, specific heat and thermal conductivity.

PROVIDED BENEFITS

A correct evaluation of the specific heat by means of the LFA has been demonstrated by comparison with the results achieved by the standard DSC technique. In this way, the acceptance and utilisation by the market of the developed solutions can be favoured.

THERMAL STORAGE ARCHITECTURE AND MATERIALS

1 Liquid lead as heat transfer fluid as technology transfer from nuclear fission to CSP of high-temperature lead-based thermal fluid.

PROVIDED BENEFITS

Because of the higher stability and continuity of the heat supply ensured by the lead storage, the solar heat collected can be used also as high-temperature process heat, significatively extending the range of possible applications of concentrated solar thermal plants.

2 Corrosion resistant alumina forming steels: innovative FeCrAl-alloys with better performance than reference commercial ones (good corrosion resistance in liquid lead at 750°, minor oxidation, self-healing properties) used for the construction of steel piping and plates of the CSP full-scale demo.

PROVIDED BENEFITS

- Raw material reduction: partial substitution of chrome through both composition (lowering Cr by replacement of 4% Al) and by increased performance (increasing oxidation resistance) as compared to standard stainless steels and Ni superalloys.
- Liquid lead applications up to 750° enabled, thus achieving increased thermal efficiency of CSP plants.
- Results in terms of characterization of FeCrAL steels transferrable to the Lead-cooled Fast Reactor (LFR) community.

3 Optimized robotic GMAW welding procedures and SAW Strip Cladding to be used with NEXTOWER innovative alloy at high temperature strength of the welds: defect free coatings on NiFeCr high temperature resistant steels (no liquation cracks, nor solidification cracks).

PROVIDED BENEFITS

Greater repeatability and faster execution of the welding process compared to a semi-automatic procedure

4 Up to 100 kW demo pilot plant including:

- the improved open volumetric receiver
- an innovative single-tank thermocline indirect thermal energy store (TES) system using liquid lead as heat storage medium installed and tested at Plataforma Solar de Almeria.

PROVIDED BENEFITS

- Compact and efficient thermal energy storage system based on a liquid heat storage medium.
- Flexible plant operation and dispatchable production
- Ease of integration with high-temperature power cycles using compressed gases or supercritical fluids as working media