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Distributed m-CHP generation form a small scale concentrated solar power

Summary

The present work describes the realization of a modular 1-3 kWe, 3-9 kWth micro Combined Heat and Power (m-CHP) system based on innovative Concentrated Solar Power (CSP) and Stirling engine technology. The cogeneration of energy at distributed level is one of leading argument in large part of energy policies related to renewable energy resources and systems. This CSP m-CHP will provide electrical power, heating and cooling for single and multiple domestic dwellings and other small buildings.

Keywords: small scale CSP, micro combined heat and power, distributed energy generation.

1. Introduction

The development of a new cogeneration system, based on a compact concentrated solar power is highly required both for industrial and distributed applications, realized compatibly with the market levellized energy cost (LEC) and with the overall objective to achieve in short medium term a grid parity. Such system (see Fig. 1) integrates small scale concentrator optics with moving and tracking components, solar absorbers in the form of evacuated tube collectors, a heat transfer fluid, a Stirling engine with generator, and heating and/or cooling systems; it incorporates them into buildings in an architecturally acceptable manner, with low visual impact.

Three main themes have led to the development of this proposal:

- improvements in glass technology allow the adaptation of large parabolic trough solar concentrator technology for much smaller scale systems, down to the single domestic dwelling and newly developed Cermet coatings can provide improved optical behavior and material durability for absorbers inside evacuated tube collectors, at higher temperatures than previously possible, leading to lower emittance and higher efficiencies ;
- high energy density Stirling engine and new compact heat exchanger technology can improve the costs and performance of small heat engines, so that they can operate with higher proportions of Carnot efficiency on the intermediate temperatures (~ 300 °C) from the new CSP collectors;
- the high cost and low power efficiency of gas-fuelled m-CHP systems, combined with increases in natural gas prices, both absolute and relative to electricity prices, can under-mine the financial viability of gas-fuelled m-CHP.

This paper will describe the first phases of development of the solar technology, where seven main partners from five European countries are collaborating.

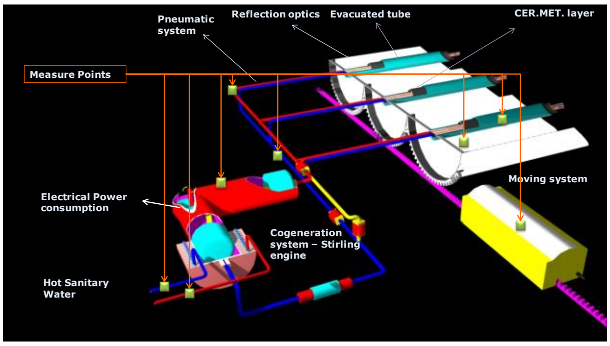

Fig. 1 - Schematic picture of the m-CHP system under development within DiGeSPo project.

Fig. 2 - Details from the first demonstration plant installed by ArrowPharm to produce process heat and steam.

2. Results

Some promising results have already been achieved, while developments on several technology subcomponents will be finalized through first part of 2013.

2.1. Selective absorber (Cer.Met. coating) and evacuated solar tube

Two Cer.Met. have been modelled, realized and tested. The upscaled receiver, in form of Cer.Met. coating based on TiO_2 – Nb, has been confirmed an absorptance of 0,94 and emittance of 0,1 (@350°C). A second Cer.Met. coating based on SiO_2 – W has demonstrated an absorptance of 0,93 and emittance of 0,09 (@350°C). A full evacuated solar tube has been designed and realized, with absorber of 12 mm in diameter and length in 2 meters (see Fig. 3).

Fig. 3 – Solar vacuum tubes with innovative receivers

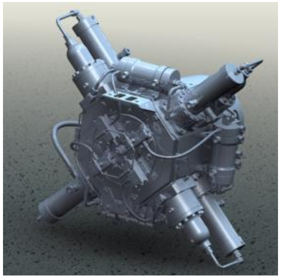

Fig. 4 - Engineering of a high energy density Stirling engine

2.2. Concentration optics

The system will be provided of a concentration ratio 12:1, and a single module will be 200 cm long, 40 cm wide and 20-25 cm high. Two or more modules can be combined. The evacuated solar tube, located on the focus, will have the selective absorber on a tube of 12 mm in diameter. A very thin glass mirror have been developed (< 1 mm). The overall mirror reflectivity has been measured, the verified value is 0,954. In Fig. 2 are evidenced the 4 optical modules.

2.3. Heat engines

Research has proposed a high energy density, double acting Stirling engine (see Fig. 4) provided of innovative heat exchangers realized through Selective Laser Melting process. The engine is a low speed (250 RPM), high pressure (130 Bars) and compact solution able to be run at 300°C and generate 3,5 kW nominal power.

3. Conclusions

The solar technology has actually entered the proof-of-concept stage. A solar plant has been installed in Malta, by Arrow Pharm company, supplying the industrial process of generated steam at 180°C and 3,5 absolute pressure. The solar collector’s efficiency is close to 47% in presence of 900 W/m^2 of direct solar radiation.

During 2013, solar evacuated tubes with innovative Cer.Met. coating, together with new thin glass mirrors will upgrade the demonstration site, together with a new and innovative low temperature difference and high energy density Stirling. By end-2013 the system will be demonstrated, with the overall objective to achieve a minimum of 65% in solar collectors efficiency at 300°C, and 12 – 15% of overall electrical efficiency by the Stirling cycle.

4. Acknowledgements

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