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Performance analysis of a solar-only gas micro turbine, with mass flow control.

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Abstract

Micro gas turbine applications in concentrating solar field systems is already on industrial stage. The peculiarity of these systems is the possibility to use fossil fuels when solar power source is lacking .It is preferable that the system works in solar-only mode for long time; however, owing to the efficiency loss which occur for low radiation levels, a fuel integration is necessary.
This work presents a system which allows to operate with constant efficiency, without the use of fuel for over one fifth of the nominal power rate. It is based on a regenerated micro gas turbine in closed loop configuration. The proposed system includes the solar tower, the heliostats field, the regenerator and a low temperature heat exchanger which cools the working fluid. Finally, two more devices, for the actuation of the proposed control are included: an auxiliary compressor and a bleed valve.
The use of air as working fluid has been analyzed, with different values of the base cycle pressure (inlet pressure of the main compressor), which are needed for varying the mass flow flowing in the system. The control of the mass flow rate is mandatory to regulate the gas turbine power, by keeping almost constant the maximum temperature of the thermodynamic cycle when the incident solar radiation changes. In particular, the auxiliary compressor admits fresh air in the cycle when the thermal power received by the sun increases, while the bleed valve discharges it in the atmosphere, when the thermal power decreases. Therefore, the thermodynamic cycle is unchanged and guarantees constant net system efficiency for all the operations conditions.
Particular attention is given to the receiver thermal incident flux, heliostat field and solar tower design. The current results are compared with the annual efficiency and energy production of an existing plant in hybrid configuration (solar-fuel).The analysis has been carried out on a commercial gas turbine having a power of 100 kW, sited on Seville town. For the heliostat field analysis, the open source code Solar PILOT has been used, while for the entire plant the code Thermoflex has been employed.

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Keywords: Micro gas turbine, solar tower,concentrating solar power, air cloosed loop Brayton cycle

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1. Introduction

Gas turbines driven by concentrating solar system concept is not recent, but some study and experimental test was performed formerly during first years of '80 of last century. Scheuerer [1] and Schmuttermair [2] used a modified Allison 250-C20B helicopter engine for their test; their research activity laid the groundwork for pressurized air receiver design, as well as dynamic simulation and control of solar gas- turbines.

During 2000s EU-funded projects have supported and examined some small-scale hybrid solar gas-turbines such as Solgate [3] and Solhyco [4] projects.

These projects have demonstrated the possibility of using a solarized micro gas turbine unit up to 250 kW, and for this reason different height temperature pressurized solar air receivers, with outlet air temperature up to 900 °C, were developed.

The FP6 Solhyco project also demonstrated the potential of using sustainably derived biodiesel as a hybridization fuel.

The FP7 EU funded Solugas project allowed the construction of a solar hybrid gas turbine system of about 5 MWe based on a SolarMercury 50 [5].

Some studies about the possibility of solar gas-turbine were performed by a research group financed from Google too, for 1 MW engine power rating.

Currently, the only gas turbine solar hybrid system available on the market is produced by Aora-Solar [6] providing a unit 100 kW for off grid and cogeneration applications and installed successfully as test in Spain and Israel.

Nowadays the attention, in CRS (central receiver systems), is posed on the use of solar-only driving to achieve high cycle efficiency and zero emission. Examples are the systems based on SCO2 solar gas-turbine [7] and, recently, the use of air as HTF [17] or Synthetic oil [19] coupled with storage.

Energy policies are promoting implementation of renewable energy systems focusing on the sources such as wind or solar, by providing management tools such as Sustainable Energy Action Plans [8].

Yet, the associated scenario with high share of renewable energy generation requires a deep understanding of the interaction between the new green production and the existing fossil-based one.

Recent studies demonstrated how the transition could be handled starting from introducing a renewable fraction in the well-established technologies already installed in the buildings such as boilers [9] or Combined Heat and Power [10].

Indeed, different technologies from prime mover to heat producer could be coupled with renewable-based systems. This is the pathway for systems' hybridization. Furthermore, another viable option is the partial or total substitution of the fuel for feeding the machines by the use of synthetic ones coming from biomass treatment, fossil fuel reforming, water electrolysis or gas hydrates [11].

This strategy could be successfully driven if local policy instruments are available along with energy analysis such as for urban contexts [12].

In this paper, the coupling between a micro-gas turbine driven by only solar tower and receiver system is presented; above all, the authors examined the possibility of using air as a working fluid.

Plant description

Figure 1 shows the plant of the proposed system. It is possible to note the main compressor (1), the solar tower (2), the turbine (3), the heliostat field (4), the recuperator (5), the low temperature heat exchanger (6), the auxiliary compressor (7), the bleed valve (8), and the evaporative tower (9).

The air mass flowing in the plant loop varies depending on DNI and sun position. When the irradiance rises, the auxiliary compressor sends air to the suction side of the main compressor (or micro gas-turbine inlet); vice versa, when sun power decreases, the bleed valve discharges air towards the atmosphere.