Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 126 (201709) 667–674

Energy Procedia

www.elsevier.com/locate/procedia

72nd Conference of the Italian Thermal Machines Engineering Association, ATI2017, 6-8 September 2017, Lecce, Italy

Thermo-Economic Analysis of a hybrid solar micro gas turbine power plant

Maria Cristina Cameretti*, Roberta De Robbio, Emanuele Pirone,Raffaele Tuccillo

University of Napoli Federico II

Abstract

This work proposes a hybrid system based on a micro-gas turbine plant integrated with a solar field either to provide a part of the heat addition or to totally replace the combustor in the case that the only solar heat input is enough to ensure that the working fluid reaches the turbine inlet temperature. The system can operate in a pure combustion mode when solar irradiance is weak or completely absent during some hours in the day or seasons. The analysis is based on the simulation of the overall plant by the *Thermoflex software*, a modular program that allows assembling model with several components.

In particular, many calculations have been performed to simulate the solar-assisted cogenerating plant in different operating conditions in order to identify the optimum sizing of the solar system which reduces the annual costs or the fuel consumption and, consequently, the CO_2 emissions. Numerical results are compared with the data available from standard micro gas turbine plant. Finally, an economical evaluation by calculation the SPB (simple pay back) is obtained for all test cases to evaluate the benefit from Italian State incentives.

Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association

Keywords: Solar tower; microgas turbine; thermo-economic analysis.

* Corresponding author. Tel.: +39-081-7683299
E-mail address: mc.cameretti@unina.it

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association
10.1016/j.egypro.2017.08.295

1. Introduction

The climate change, the depletion of fossil fuels and rising electricity costs have become vital issues requiring investigations to increase the share of employment of renewable sources in the energy production systems. Among the various CSP technologies, over the last ten years, solar tower technology has gained considerable development.

In a solar tower system, the power collected from the elliptical field is strictly dependent on the height of the tower and its position with respect to the field. It is also to be specified that the best projects are strongly affected by the cost of the receiver, the charging rate and the maximum receiver temperature used. In [1] an example of a new procedure, with a fully thermo-economic optimization for the design of the collector field of an actual SPT system, is presented. Hybridization is a newly proposed concept in which solar thermal energy provides a portion of the required thermal input instead of fossil fuels and natural gases [2]. Storage and intermittency concerns regarding solar energy make hybridization a viable solution to increase renewable energy share in power generation Actually, the current level of maturity limits the contribution of solar energy due to intermittent and storage problems.

Thermal systems, which are generally designed and analyzed based on the nominal design point, given the intermittence of the radiation, will operate for most of the year well above or below the nominal operating point.

It is worth-noting that if a latent heat accumulator is used, the incoming temperature of the receiver can vary without problems, but presently there is a clear lack of knowledge on how to handle off-design conditions in terms of developing appropriate control strategies to maximize the heat output of the receiver and its operating range. The study [3] investigated two control strategies - a fixed receiver flow rate (FF) and fixed receiver outlet temperature (FT) - for their off-design performance in each of two off-design operational modes (storage and non-storage). Solar field utilization (SFU) is variable in non-storage mode, but in the storage mode, it is whether variable or fixed at design point. Esmail and Mokheimera [4] provide an investigation into the technical and economic feasibility of a CSP plant with the integration of a gas turbine equipped with a cogeneration plant which is progressively installed in Saudi Arabia. Different designs of hybrid solar/fossil fuel gas turbine cogeneration systems have been proposed. A solar tower plant is considered with linear parabolic collectors and Fresnel reflectors coupled respectively to a gas turbine plant. For each of these CSP alternatives, the mass flow rate and the inlet temperature of the turbine are considered to be constant as to generate electricity. A software was used to analyze the performance of the plant. As far as the economic technical comparison is concerned, reducing the CO_2 emissions. The new model presented by M.J. Santos et al [5], evaluates radiation variations and environmental conditions, considering the solar part running only when the radiation is fairly high. A combustion chamber tries to keep the temperature constant at the turbine inlet in order to obtain a constant output power. The performance of the entire plant is written as a combination of the thermal performance of the heat exchanger and the required heat exchanger. Numerical values of model input parameters are taken from a central tower installation recently developed near Seville, Spain. Research findings show that the hybrid has the right potential to generate a stable power with consumption and, consequently, reduced emissions. Real data for irradiance and external temperature are taken in hourly terms.

The OMSoP project [6], funded by the European Commission, aims to use a Brayton cycle with a gas microturbine replacing the more conventional Stirling engine in order to increase the relationship between the electric power generated by the collected solar energy and improving the operability in relation to solar energy short time fluctuations. The work deals with the activities carried out so far by ENEA, which is principally involved in the development and experimental characterization of the dish component, and in the integration of the complete system, both in terms of modeling and realization. In [7] the authors find similar behaviors of the two solutions at the same area as the solar collectors, by comparing the behavior of a hybrid solar gas turbine cycle, in which the compressed air exiting the compressor is sent to the solar tower before entering the combustion chamber, and a combined cycle coupled with a linear parabolic collector. They evaluated the performance of the plants under real operating conditions due to the use of commercial software. The interest in solar-turbine (HSGT) turbine systems in solar tower systems is growing. This is due to the high conversion efficiency and low water consumption that is obtained when a combined cycle is implemented. J. Spelling et al. [8] have developed a dynamic simulation model of a solar-hybrid system with the aim of determining its thermodynamic and economic characteristics. The end is to determine the optimal design by minimizing the cost of energy and CO_2 emissions. The simulated plant has a power of 15 MW which must reach the different solar irradiation conditions. The solar-gas turbine hybrid solution is the best solution to reduce CO2 emissions from an open gas turbine cycle. As a result, the energy cost of the energy has a slight