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A small size combined system for the production of energy from renewable sources and unconventional fuels

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Abstract

Nowadays, the development of new power plants capable of effectively using non-conventional energy sources is strongly desirable in order to obtain a significant reduction in costs of energy. In this regard, this paper proposes a new small scale (about 100 kW) combined cycle plant which can be fired externally by any kind of biomass. Particularly, the research activity presented here is concerned with the preliminary design of this innovative plant, which will be built, by means of a project funded by "Apulia Region", at the LabZero Research Centre of Polytechnic University of Bari in the south of Italy. The goal of the paper is to demonstrate the effectiveness of the plant in terms of energy efficiency and availability and reliability of its components. The plant is mainly composed of a centrifugal compressor and a centripetal turbine of an automotive turbocharger, with the working fluid (clean air) being heated in a high temperature heat exchanger (HTHE) by using hot flue gases produced in an external combustion chamber burning biomass. The clean hot air expands in the turbine and then feeds the combustion chamber, where biomass is burned. In order to increase the efficiency, the flue gases exiting the HTHE are delivered into a heat recovery steam generator to generate water steam which can finally expand through a rotary actuator. Two configurations, employing an open Rankine cycle and a close one respectively, are analysed, and the use of biomass is compared with methane.

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*Keywords:*Biomass; Externaly fired microturbine; Combined cycle plant.

1. Introduction

In spite of the insistent calls of the international community about energy saving, current energy systems are still strongly based on the use of fossil energy. The past years highlighted the long-standing problem of energy supply, especially for those countries that are subject to lack of fossil sources, whose availability is often expensive and jeopardized by geo-political aspects. Thus, it is necessary that research focuses on the development of novel technologies and methodologies for electricity generation that have the potential to save energy and increase eco sustainability. A solution is represented by the decentralization of power generation, employing small size plants

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fired by unconventional fuels such as biomass [1,2,3] (i.e. pellets [4] or discarded agricultural by-products) for distributed energy generation. Since biomass is largely available and given its low impact in terms of pollutant emissions [5], a more thorough evaluation of its potentiality is a mandatory step to decouple power generation from large scale plants, which can only be powered by fossil fuels.

In this scenario, the purpose of this work is to design a small size combined cycle power plant that greatly fits with energy demands typical of limited urban areas, i.e. community housing, leisure centres, tertiary sector users, sport centres, hospitals or supermarkets. The pilot plant will be located in Apulia (south of Italy), and this kind of plant is interesting especially for those regions, such as Apulia, that offer a widespread availability of agricultural and forestry waste products to be used as biofuel, e.g. those deriving from the cultivation of olive trees [4,6,7] (in Apulia, the quantity of olive trees is estimated around the 40 millions of units). The strategic aspect of great importance is that the biomass supply can be feasible at competitive costs; however, it must be considered that some typologies of biomass are annually available over a limited period, for example, olive oil by-products (vegetation water, olive pomace, exhausted peanut residue) are available in Apulia only from mid-October to late February. For these reasons, the proposed power plant is designed in order to allow burning of most of the biomass derived from agricultural and forestry wasted products typical of Apulia, such as hazelnut shells, cherry stones, grape seeds, almond shells, olive stones, etc. This multi-fuel approach is allowed by the similar LHV values of such agricultural by-products. It is obvious that, in case of unforeseen lack of biomass fuels (e.g. caused by inefficiency of collection systems, packaging, transport and storage systems [7,8,9,10]), natural gas or other clean fuels can be employed in place of biomass and burned in a commonly used combustor for gas turbines [11]. This strategy can allow both a smart use of the available fuels and maintenance of the biomass combustor, in fact the temporary use of clean fuels can allow cleaning devices to remove ash from the combustor (the biomass combustion implies large production of ash).

The operating principles of this novel small power plant are described in detail in this paper, particularly two different configurations are proposed in the next sections. Afterwards, the mechanical and thermal components are described, and their availability and reliability are discussed. Finally, the results of the numerical simulations, achieved with the Gate-cycle software and an Excel program to predict the efficiency of both the configurations, are shown and discussed critically.

Nomenclature

G_A	air mass flow rate
G_B	fuel mass flow rate
G_S	steam mass flow rate
P_{el}	electrical power
p	pressure
h	enthalpy
T	temperature
HRSG	heat recovery steam generator
HTHE	heat temperature heat exchange
LHV	lower heating value
β_C	compression ratio
ΔT_{pp}	ΔT at pincth point
ε	heat exchanger efficiency
η_g	plant (electrical) efficiency
η_{is}	isentropic efficiency
η_B	Combustion efficiency
λ_V	water latent vaporization heat