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Performance analysis of combined microgas turbines and gas fired water/LiBr absorption chillers with post-combustion

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Abstract

The integration of microgas turbines (MGT) and absorption chillers is an emerging technology that uses a wide range of fuels to produce electricity, cooling and heating simultaneously for small scale distributed generation in grid connected or isolated locations.

This paper studies the performance of MGTs of different power capacities directly coupled to double-effect water–LiBr absorption chillers. In these systems the MGT exhaust gas is the heating medium to drive the chiller. Also post-combustion natural gas is used to increase the cooling capacity of the system. The paper analyses the effect of the post-combustion degree on the integrated system performance of four MGT power sizes. Two cases are considered. In the first, fresh air is added together with the post-combustion natural gas and in the second it is not added. In the latter case the oxygen necessary for the combustion reaction is extracted from the MGT exhaust gas stream. For the sake of comparison a study is also made of the performance of a more conventional system consisting of an MGT and a hot water heat exchanger to drive an absorption chiller. The main advantages of the new technology over this conventional system are that the COP of the chillers is higher because they are driven by higher temperatures, the production of electricity and chilled water is decoupled and there is a wider range of chilled water production capacity.
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Keywords: Microgas turbines; Absorption chillers; Heat integration

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1. Introduction and objectives

The new distributed generation equipment coming onto commercial and industrial markets provides waste heat that can be applied to absorption cooling. This significantly increases overall system efficiencies. On the other hand, expanding power demands, increasingly restrictive environmental regulations and the deregulation of the electricity market are providing an opportunity for developing these new on-site distributed generation technologies such as microgas turbines (MGT). MGT technology can be integrated in distributed power generation systems to produce electricity, heating and cooling simultaneously for air conditioning and industrial applications although such uses as vehicle propulsion are also currently under development. The main advantages that they have over other competing technologies are the fuel flexibility, low emissions, quiet operation and low maintenance [1,2].

The electrical efficiency of the current regenerative MGTs, which are also characterised also by low pressure ratios and modest turbine inlet temperatures, is in the range of 25–30% depending on the MGT size. Thus if the overall system efficiency is to be competitive the waste heat available in the MGT exhaust gas must be effectively recovered. In warm climates such as the Mediterranean where there can be long hot periods, so-called trigeneration systems (power, hot and chilled water) are a better alternative than the simple cogeneration system for producing only power and heat. Absorption refrigeration systems can be used in combination with MGT to recover MGT waste heat so that chilled water can be produced and the electric load demanded by the more conventional compression refrigeration systems reduced or eliminated.

Nowadays the only commercially mature technology for cooling using absorption chillers for small power applications in combination with MGT is the one using an intermediate gas/water heat exchanger that produces hot water to drive the absorption system. Because of the low temperatures, only single-effect absorption chillers can be used. So the existing MGT/absorption systems are too limited: their COPs are too low, the range of chilling capacities are not wide enough, and electricity and cooling capacity depend completely on each other, etc. For these reasons it was decided to analyse the possibility of using the exhaust gas in direct fired absorption machines with the option of natural gas post-combustion. Direct-fired chillers are more efficient and better positioned in the refrigeration market than their hot water driven counterparts.

Some research projects are being carried out into direct MGT exhaust gas fired absorption systems although not all of them use cofiring. The most well known are the CEEE project at the University of Maryland [3], Southern California Gas Co., Takuma/Capstone and Ingersoll–Rand/Hussman all in the USA, the University of Pisa project in Italy [4] and the Icogen S.A. development in Spain. Some new small ammonia/water generator–absorber heat exchange (GAX) chillers are promising because they can be driven directly by exhaust gas and do not require a cooling tower [5]. These GAX systems are entering the market now (2004) [6].

The objective of this paper is to study the integration of MGTs and double-effect direct-fired absorption systems. The exhaust gases from the MGT are directed to the absorption chiller with the option of additional natural gas post-combustion. Two cases are considered. In the first, fresh air is added together with the post-combustion natural gas. In the second, fresh air is not added and the oxygen necessary for the combustion reaction is extracted from the MGT exhaust gas stream. A comparison is made with a similar system that uses a hot-water driven absorption system. Before the modelling characteristics and the results are presented, the current technology

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