Proceedings of EFC2017
European Fuel Cell Technology & Applications Conference - Piero Lunghi Conference
December 12-15, 2017, Naples, Italy

EFC-17029

NUMERICAL ANALYSIS OF A CHCP SYSTEM COMBINING AN ABSORPTION CHILLER AND A LOW TEMPERATURE PEM FUEL CELL.

Andrea Luigi Facci* and Gabriele Loreti*
*Department of Economics, Engineering, Society, and Business Organization. University of Tuscia, (*Italia*)

Abstract **- The utilization of absorption chillers to fulfill the refrigeration demand boosts the effectiveness of CHP systems. In this paper, we analyze the performance of a CHCP plant that integrates a low temperature PEM fuel cell and an absorption chiller. The plant, is simulated through a thermochemical model implemented in AspenPlus. Then, we evaluate the effective performance of the CHCP plant, in a real energy management scenario.**

Index Terms **– CHCP, Absorption chiller, optimization, PEM**

I. INTRODUCTION

CHP coupled with district heating and cooling could significantly help to increase the efficiency and to reduce the environmental impact of buildings [1,2].

Fuel cells, and specifically PEM-FC, are addressed as one of the most promising technologies for distributed energy generation [2,3]. Absorption chillers can be profitably utilized to improve the effectiveness of CHP systems by facilitating the heat recovery in warm seasons.

In this paper we propose an innovative energy system configuration that integrates an absorption chiller and a low temperature PEM-FC in a CHCP plant.

II. METHODOLOGY

We consider a CHP plant based on a low temperature PEM-FC including: (i) a fuel processor that converts pipeline natural gas into high purity H_2; (ii) and an automotive derivative FC that produces electrical and thermal power; (iii) a single effect absorption chiller.

The baseline plant, described in details in [4], has been here modified, as represented in Fig. 1, to allow the integration of the absorption chiller within the CHP plant. The fuel processor layout has been updated to allow the heat recovery of about 15 kW of thermal energy in addition to the 80 kW obtained from the FC. This modification also increases the temperature of the obtained water up to 95°C that can be considered the minimum temperature to feed the absorption chiller.

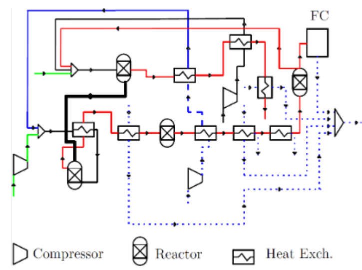

Fig. 1. Layout of the proposed power plant.

Due to the relatively low temperature of the cogenerated heat, we consider a single effect absorption chiller, whose layout is depicted in Figure 2.

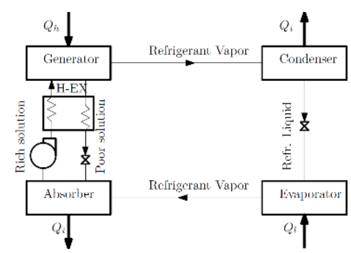

Fig. 2. Single effect absorption chiller layout.

The design and off design performance of the power plant is retrieved through a thermodynamic lumped parameter approach, except for the PSA and the FC that are simulated through black-box phenomenological models. Simulations are carried out in Aspen Plus [5].

The control strategy determines the effective performance of a CHP plant as much as the design efficiency of its components [6-8]. To assess the effectiveness of the proposed energy system we first determine the optimal control strategy for a full year of operation through the methodology proposed in [9,10].

Finally, we compare the energy cost, and the primary energy consumption of the proposed plant to those relative to separate production and to the baseline plant.

III. RESULTS AND DISCUSSION

The performance of the CHCP plant are reported in Fig. 3. T the efficiency of the FC is maximized at part load. Thereafter, such a prime mover is particularly suited to effectively follow the variable energy demand in DG systems. Moreover, the maximum efficiency (38%) is larger compared to alternative technologies of this power (i.e. internal combustion engines).

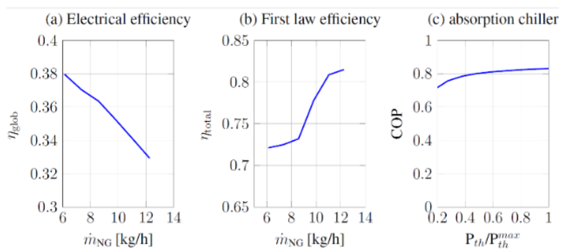

Fig. 3. Performance of the CHCP plant as a function of set-point.

The COP of the absorption chiller, reported in Fig. 3(c) is relatively low, due to the low grade of the input thermal energy. However, it is designed to utilize energy that would otherwise be wasted, contributing to improve to performance.

To assess the plant behavior in a realistic energy management scenario we assume that it serves a building composed of 4 residential units, whose energy demand is retrieved from [12]. The costs of electricity and natural gas are 22 c€/kWh and 15 €/GJ respectively.

	Cost [k€/year]	*PEC [TJ/year]*	*PBP [Year]*
Reference	230	9.02	NA
Baseline CHP	100	6.21	3
Modified CHP	90	5.22	4

Tab. 1 Relevant performance of the considered CHP plants.

Tab. 1 show that both the baseline and the modified plant significantly reduces energy cost and primary energy consumption. For the Pay back Period we assumed that the costs of the FC and of the absorption chiller are 3000 €/kW and 1200 €/kW respectively. The introduction of absorption chillers boost the plant performance, reduces the energy cost by 60% with respect to the separate production and by 10% with respect to the baseline CHP. Similarly it reduces the PEC by 42% with respect to separate production and by 16% compared to the baseline CHP.

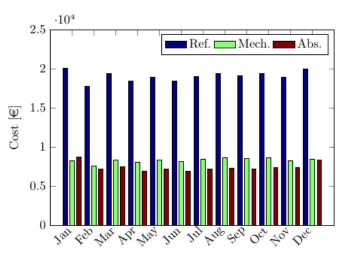

Fig. 4: Seasonal variation of the energy cost.

The absorption chiller is particularly effective in reducing the energy cost during summer and transitional seasons (see Fig. 4) for the larger chilling demand.

IV. CONCLUSION

The results of this study evidence that small scale PEM - CHCP plants can effectively contribute to improve the energy performance in the residential sector. Moreover, the development of small absorption chillers could significantly contribute to enhance the effectiveness of such plants, in terms of economic sustainability and energy efficiency.

ACKNOWLEDGMENT

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking under grant agreement No 671396. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation program and United Kingdom, Germany, Greece, Croatia, Italy, Switzerland, Norway. Swiss partners are funded by the State Secretariat for Education, Research and Innovation of the Swiss Confederation.

REFERENCES

[1] International Energy Agency. Combined heat and power evaluating the benefits of greater global investment; 2008

[2] F. Cappa, A. L. Facci, S. Ubertini, Proton exchange membrane fuel cell for cooperating households: A convenient combined heat and power solution for residential applications, In Energy, Volume 90, Part 2, 2015, Pages 1229-1238, ISSN 0360-5442.

[3] Brown JE, Hendry CN, Harborne P. An emerging market in fuel cells? Residential combined heat and power in four countries. Energy Policy 2007;35:2173e86.

[4] A. L. Facci, G. Loreti, S. Ubertini, F. Barbir, T. Chalkidis, R. P. Eßling, T. Peters, E. Skoufa, R. Bove, Numerical Assessment of an Automotive Derivative CHP Fuel Cell System, Energy Procedia, Volume 105, 2017, Pages 1564-1569.

[5] Aspen Tech, Aspen Plus Unit Operation Models Reference Manual

[6] A. Facci, L. Andreassi, F. Martini, S. Ubertini Comparing Energy and Cost Optimization in Distributed Energy Systems Management. ASME. J. Energy Resour. Technol. 2014;136(3):032001-032001-9.

[7] A. Facci, L. Andreassi, F. Martini, S. Ubertini Optimization of CHCP Operation Strategy: Cost vs Primary Energy Consumption Minimization. ASME. ASME International Mechanical Engineering Congress and Exposition, Volume 6A: Energy

[8] A. L. Facci, L. Andreassi, S. Ubertini, Optimization of CHCP (combined heat power and cooling) systems operation strategy using dynamic programming, In Energy, Volume 66, 2014, Pages 387-400, ISSN 0360-5442

[9] A. L. Facci, L. Andreassi, S. Ubertini, E. Sciubba, Analysis of the Influence of Thermal Energy Storage on the Optimal Management of a Trigeneration Plant, In Energy Procedia, Volume 45, 2014, Pages 1295-1304, ISSN 1876-6102

[10] US Department of Energy. Buildings energy data book; 2012. http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx.