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ANALYSIS OF THE PERFORMANCES OF A FUEL CELL CHP SYSTEM UNDER DIFFERENT ENERGY DEMAND AND CLIMATE SCENARIOS

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Abstract **– In this paper we assess the effective performance of a cogeneration plant based on low temperature PEM fuel cells in different energy scenarios. We vary the energy demand (office apartment district, clinic, hotel, and supermarket) and the climatic condition (Hot, Cooling Based, Moderate, Heating based, and Cold). We also consider two control strategies: one that minimizes the energy cost, and one that minimizes the primary energy consumption. The plant performance is analyzed comparing the energy cost and the primary energy consumption to the business as usual scenario. The payback time is also evaluated to assess the economic feasibility to the plant.**

Index Terms **– CHP, Fuel Cells, Climate conditions, Energy demand.**

I. Introduction

The International Energy Agency (IEA) estimates that CHP systems together with district heating and cooling could save 950 Mton/year of carbon dioxide emissions by 2030 [1]. Fuel cells, and specifically PEM-FCs, are one of the most promising prime movers for distributed energy generation [2-4] due to their flexibility, high efficiency, reduced noise, and low pollutant emissions.

In this paper we estimate the economic feasibility, and the effective reduction of primary energy consumption of a PEM-FC based CHP plant for different building scenarios.

The effectiveness of a power plant is largely determined by its control strategy [5-9]. Therefore, a management policy must be hypothesized to estimate economic feasibility, profitability and energy impact of the plant. Here, we consider two optimized control strategies: one that minimizes the energy cost, and one that minimizes the primary energy consumption.

II. Methodology

We study the CHP plant schematically represented in Fig. 1. The performance of the plant components is retrieved from literature [10,11] and varies as a function of the set-point.

We utilize the methodology introduced in [6,8,9] to determine the plant control strategy. Such a methodology minimizes a prescribed objective function though a graph based algorithm.

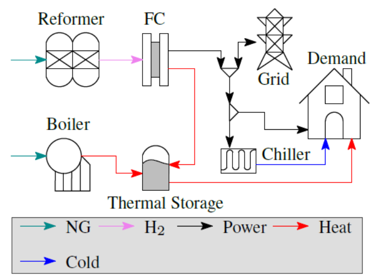

Fig 1. Schematic of the CHP plant in study.

We consider two different objective functions, minimum cost and minimum primary energy consumption (PEC), and we apply the methodology to 25 different energy management scenario obtained combining 5 buildings (office apartment district, clinic, hotel, and supermarket) and 5 climatic conditions (Hot, Cooling Based, Moderate, Heating based, and Cold).

The energy demands for all the buildings and climates are retrieved from the “Reference buildings database” of the DOE [12].

For the economic analysis we assumed that the capital cost of the CHP plant is 2000 €/kW, the cost of electricity is 11.02 c€/kWh and the cost of natural gas is 6.54 €/GJ.

III. Results and discussion

PEC reduction, cash flow and pay back time are sistematically represented for all the considered cases in Fig 1 (economic optimization) and in Fig 2 (PEC minimization). Cogeneration consistently reduces the energy cost and the primary energy consumption for all the considered cases irrespective to the hypothesized control strategy.

According to economic optimization, PBP is below 10 years for all the considered cases, and is between 4 and 5 years for all the building typologies, except for the hotel and the office in moderate climate. The PBP is only marginally influenced by the climatic oncditions. However, colder climates have genereally lower PBP, larger cost reduction and lower primary energy consumption. In fact, a colder climate facilitates the heat recovery from the prime mover thoughout the year, improving the total system efficiency.

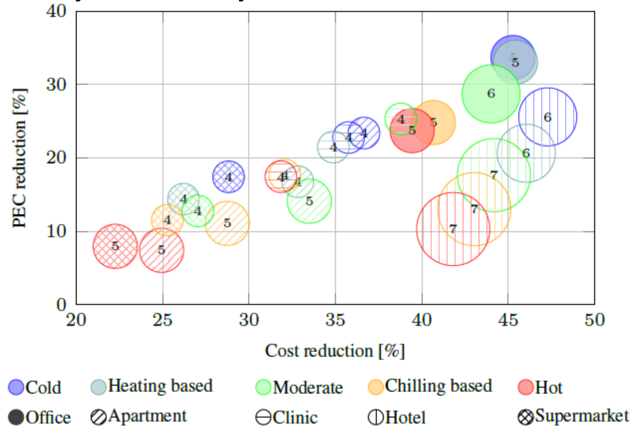

Fig 2. Comparison between the different scenarios for the minimum cost strategy: the area of the circles is proportional to the PBP.

Also PEC minimization allows a significant reduction of energy costs, as evidenced in Fig. 3. Moreover, switching from economic optimization to PEC minimization boosts the impact of CHP on the energy system. In fact, the PEC is reduced up to 70% with respect to cost minimization. The improvement of the energy efficiency is more relevant in hot climates, where exploiting CHP is more complicate. Such an improvement of the energy performance requires an increment of the expenses. However, the cost increment is relatively limited being in the range [2.5%, 20%]. Similarly, the PBP is incremented by only 1 year and the economic feasibility of the proposed plant is not compromised switching from economic optimization to PEC minimization.

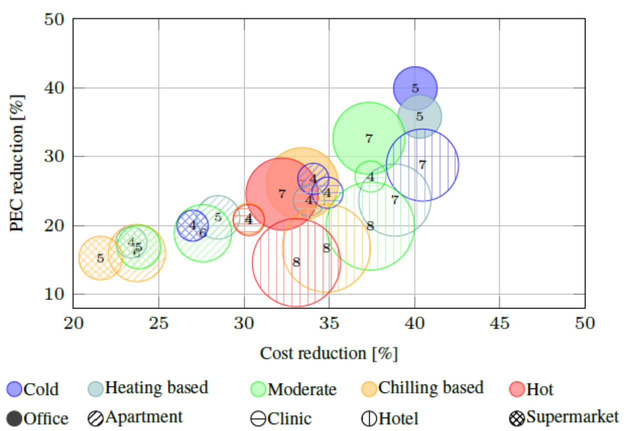

Fig 3. Comparison between the different scenarios for the minimum PEC strategy: the area of the circles is proportional to the PBP.

IV. Conclusions

In this paper we systematically demonstrated the effectiveness of an innovative CHP plant based on low temperature PEM fuel cells. Moreover, we assessed the effects of the management policy on the plan economic profitability and efficiency. The presented analyses clearly demonstrate the role of the control strategy, and suggest to PEC minimization should be favored with respect to economic optimization. In fact, PEC minimization yields significant improvements of the system efficiency with only moderate economic penalties.

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