Universidade do Minho

Escola de Engenharia

Semana da Escola de Engenharia
October 24 - 27, 2011

DEVELOPMENT OF A THERMO-ECONOMIC MODEL FOR A MICRO-CHP SYSTEM: HEAT DEMAND ASSESSMENT

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KEYWORDS
Cogeneration, Optimization, Thermal Demand.

INTRODUCTION

In recent decades, there has been a deep change in energy policies. In fact, as energy needs are growing and due to the predictable scarcity of fossil resources, it is very important to define better strategies to reduce the economic and energy dependency of this kind of sources. The liberalization of the energy market, the search for alternative technologies, the sustainability of energy supply and the socio-environmental concerns are emphasizing the implementation of high efficiency technologies (Konrad et al. 2009).

Cogeneration is an example of such technologies, due to the fact that these plants typically consume less 20% of input energy when compared with the traditional production of heat and power in separate systems, allowing the use of the heat that would normally be wasted in the power generation process. Additional environmental benefits are deeply related to the reduction of primary energy consumption, since a lower amount of burned fuel means a reduction in pollutant gas emission. Also, the competitiveness of these systems has gained a greater expression with the recent policies which largely promote the efficiency and the sustainable development of the energy sector. In Europe, the Energy Performance of Buildings Directive (EPBD, 2002/31/EC and the recast 2010/31/EU) opened new opportunities for small-scale systems applied to the buildings sector, by ensuring that the economic feasibility of high-efficiency alternative systems such as cogeneration is taken into account, before the construction of new buildings or in the refurbishing of existent large to medium-size ones.

All these topics represent a good research opportunity for the numerical optimization of energy systems integrating technical and economic aspects. The main idea behind the present PhD research work is the development of a numerical optimization model to assess the viability of a new micro-CHP system based on Stirling engine technology combined with a solar collector, proposing the use of a renewable energy source. The variables that must be considered in the economic model were already identified through a cost-benefit analysis (Ferreira et al. 2011), being the system sizing the next step in the model development. This extended abstract presents the implemented methodology to estimate the thermal energy consumption for a residential building in order to properly size the micro-CHP system.

METHODOLOGY

For the model development, it is required to set the heat and power output values to size the micro-CHP plant according to the needs for which the system is intended to fulfil. In Portugal, as fixed feed-in-tariffs are applied, all the produced electricity can be sold to the grid in order to benefit from a higher price (Figure 1).

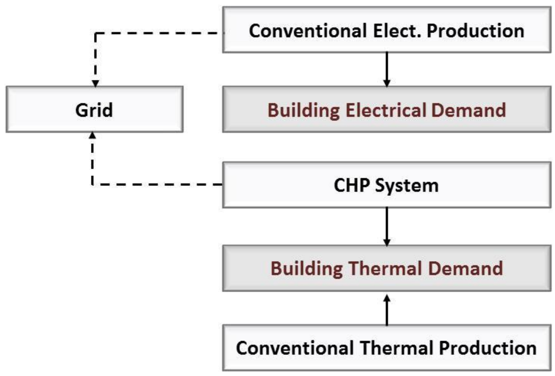

Figure 1: Conceptual Operation of a Cogeneration System with Grid Connection

However, and according to the Cogeneration Directive (2004/8/EC), the cogeneration systems should operate based on the useful heat demand of the building, being of utmost importance to match the thermal capacity of the CHP plant to the building's thermal load.

So, the annual total thermal power duration curve of a particular building is needed and, although it is usually obtained from a complex yearly thermal simulation, a good/simple estimate can be achieved from the sum of the hourly heating load plus the hourly domestic hot water needs, calculated according to the Portuguese regulation for the thermal behavior of buildings (RCCTE, Decree Law 78/2006).

Heating Load

In order to determine the heating load, the specific winter heating demand (Ni) per unit of floor area (kWh/m^2), has to be calculated. This parameter expresses the amount of useful energy required to keep a building to a reference temperature during the heating season. In this study the data were calculated for a reference B- class building located in Oporto, for which the duration of heating season is 6.7 months. This heating demand depends on the Form Factor (FF) and on the Heating Degree Days (HDD). The FF corresponds to the building envelope area divided by volume. The HDD is a parameter that characterizes the severity of the climate during the heating season, corresponding to the sum of positive differences between the air inside reference temperature (20ºC) and the local climate temperature during this period.
In the presented work, it was considered a FF of 1.0 and, according to the RCCTE, the correspondent value of HDD in the city of Oporto is 1610 ºC.*days*. The specific winter heating demand can, thereby, be achieved by the Equation (1).

$$Ni = 4.5 + (0.021 + 0.037FF)GD \qquad (1)$$

From Ni, a global heat loss coefficient was calculated in $W/(m^2.°C)$ and the hourly heat demand of the building was computed based on hourly outside temperatures for the local climate (average day of each month) and floor area.

Hot Water Load

The energy needed with the daily hot water demands (Qaqs) in (kwh/m^2.*day*) can be determined by the Equation (2).

$$Q_{aqs} = M_{aqs}.(4.187/3600).\Delta T \qquad (2)$$

where M_{aqs} is the average daily consumption of hot water (in $L.m^{-2}.day^{-1}$) and ΔT is temperature increase from the grid water temperature up to the required value, 60 ºC. The average daily consumption for residential buildings was assumed as 40 liters per person and per day for an occupation of 5 persons per dwelling (150 m^2 of floor area). This methodology was applied for each month of the year taking into account the variable water-supply temperature. The hourly demand was then achieved by assuming a daily hot water load distribution as suggested by the *f-chart* method.

Annual Thermal Power Duration Curve

The annual total thermal power duration curve (Figure 2) was then obtained adding the heating and the domestic hot water loads on an hourly basis.

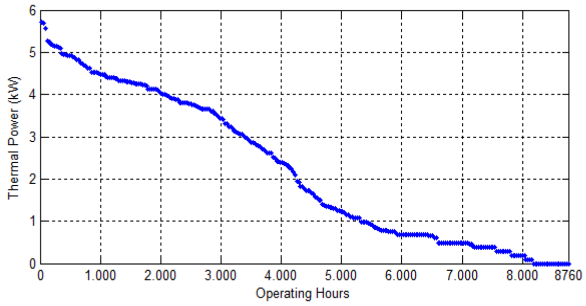

Figure 2: Annual Thermal Power Duration Curve

According to the implemented methodology, the peak thermal demand is about 6 kW_{th}. This result is within the expected values, considering that, for individual dwellings, the decentralized energy systems available in the market are characterized by a thermal power in the range of 2-35 kW_{th} (Konrad et al. 2009).

ACKNOLEDGEMENTS

The first author expresses her acknowledgments for the support given by the FCT through the PhD grant SFRH/BD/62287/2009.

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