Available online at www.sciencedirect.com
ScienceDirect
Energy and Buildings 38 (2006) 1434–1442
ENERGY and BUILDINGS
www.elsevier.com/locate/enbuild

Implementation of a cogenerative district heating: Optimization of a simulation model for the thermal power demand

L. Barelli *, G. Bidini, E.M. Pinchi

Dipartimento di Ingegneria Industriale, Università degli Studi di Perugia, Via G. Duranti, 67-06125 Perugia, Italy

Received 12 November 2005; received in revised form 17 March 2006; accepted 20 March 2006

Abstract

The district heating set up with a cogeneration system, concurs to attain energetic, economic and ambient benefits. It also provides to citizens a new service. The project strategy is based on the idea of supplying a portion of the necessary thermal power through a combustion alternative engine in cogeneration modality. It's also interesting to modulate the load with auxiliary boilers fed by natural gas. This solution allows to save primary energy, create a centralization of the energy production, which contributes to the problem of polluting emissions, through the decentralization of the sources. The first step to assess the technical-economic feasibility of a district heating system, based on a cogeneration plant, is to underline and to characterize the energetic request of the basin of user.

The objective of the present work is to develop a model that yields an esteem of the hourly thermal load for every days of the heating season of a complex user, represented by a single neighbourhood.

To do this, the present work proposes a new method of simulation of the daily and hourly thermal load trend, known only the value of the power installed in the thermal plant for every user, the seasonal hours of the burner operation and the timetable of the heating service distribution, more than the external mean daily temperature trend.

The results obtained using this model, have been verified with the data of seasonal consumptions, confirming the validity of the proposed methodology.The above allows to determine, with more precision, the thermal request peak to satisfy, taking in consideration the contemporaneity of the loads, also of different typology, and to carry out a better sizing of the generation plant.

Keywords: District heating; Simulation of the thermal demand; Cogeneration

1. Introduction

At this moment the situation in terms of energy and energetic resource, results critical. The stock of the fossil fuel decreases gradually and the increase of the international energy request has produced a search of objectives, ratified in the Kyoto protocol, such as the rational use of energy, the improvement of the process's efficiency, the passage towards fuel with a minor contained of carbon. But, the principal objective is to reduce the atmospheric emissions which cause the greenhouse effect.

The present work proposes to develop a model of the thermal daily and hourly load of a complex user such as a neighbourhood during the heating season. This to value the thermal power peak necessary to correctly size the generation plant supplying heat to the district heating system [1–8]. The model gives the seasonal amount of the thermal energy necessary to the buildings of the basin of user, to guarantee to the users, in function of the trend of the external mean seasonal temperature, the comfort requested.

Knowing the total request, pointing out the better configuration of the operation, it's possible to give a realistic evaluation of the fuel consumption necessary, the corresponding level of the emission in the environment, the electrical energy production and the energetic saving attainable.

The strategy chosen is foreseen to guarantee, with a combustion alternative engine in cogeneration modality, a thermal power satisfying the thermal request characterizing the user for all of the heating season, supplying the remaining power, when necessary, through traditional boilers.

In particular the study relates to the buildings, of an area comprising some neighbourhoods in Perugia, a city in central Italy, in order to arrange a district heating system combined with a cogeneration plant. This to increase the saving of primary energy obtainable, to realize the centralization of the

* Corresponding author. Tel.: +39 075 5853740; fax: +39 075 5853736.
E-mail address: barelli@unipg.it (L. Barelli).

0378-7788/$ – see front matter
doi:10.1016/j.enbuild.2006.03.023

Nomenclature

C	global heat loss
DD	Degree Day
DH	Degree Hour
T_i	internal temperature
T_{me}	mean daily external temperature
w	weights distribution

energy generation and the delocalization of the polluting production, controlling at the same time the emissions using suitable control systems.

As a first step a census of the user of this study case has been conduced; the majority of the population is composed by residential buildings and some schools.

The collected data for every thermal plant of the user, concern the combustible typology used, the seasonal consumptions, the power currently installed, the ignition hours of the burner and those of the heating service.

For every user typology, a reference model deduced from experimental data has been conceived, in order to characterize the request of the typical user.

This involves the determination of the weights distribution in 24 h defined as the ratio between the thermal mean hourly power distributed (valued as the mean of the thermal hourly powers supplied in the days of the surveys) and the thermal mean power distributed, calculated starting from the available data of all the surveys realized in the hourly ignition of the heating system.

Having determined such weights distribution, it's possible to assess the hourly trend of the inner temperature truly guaranteed with the current thermal plant.

Then the weights distribution were varied through suitable modifications in the heating system operation, implying the reduction of the thermal power peaks requested in the thermal transitory at the ignition system. The subsequent analysis of the hourly trend of the inner temperature, allows to verify the satisfaction of the thermal comfort requested.

To optimize this procedure and to obtain a more uniform daily trend of the inner temperature, the thermal transitory, considered as the period necessary to have the regime conditions in the building, was investigated. A modified thermal profile of the request, which characterizes the typical user, is obtained.

This methodology was subsequently extended to the entire heating season, utilizing the weights distribution previously obtained and creating the correlation between the external temperature trend and the thermal request. Calculation procedure was finally extended to all the typologies of users, obtaining the daily and hourly trend of the total thermal load. On this basis the methodology was verified, through the true consumption data and the generation efficiency (valued starting from the hours available data), showing the efficiency of the model proposed.

2. Characterization of the user

The users to serve consist of only residential premises, in particular 46 buildings: there are three schools and 43 residential buildings. For all of the users, the data relative to the fuel typology and consumption, the relative cost, the operation hours and the thermal power installed are available.

The experimental data gathered, have supplied the data of the thermal power in the building and the corresponding fuel consumption each minute. From this data is possible to evaluate the energetic requirement and the mean thermal power supplied in the heating season.

Currently the study area presents user majority fed by natural gas (relative to the residential buildings only two thermal plants are fed by liquid fuel with low sulphur tenor and one by gas oil; for the schools only natural gas is used).

After a census, it results that the basin of user is served by thermal plants for a total power installed of 31.500 kW. Relative to the annual consumption an amount of about 2440.000 Nmc of natural gas is obtained, on the basis of the fuel price and the total expense data available for every residential building. Moreover, starting from the latter and the efficiency of each plant, the annual thermal requirement of about 19.870 MW h results.

3. Methodology for the simulation of the thermal request of a typical residential building

3.1. The surveys

The objective of this work is to evaluate the hourly thermal load of a residential building, in every day of the heating season. It is possible, subsequently, to deduce the total thermal load for all the residential buildings, as described in the following section. In particular the analysis starts from the data of the thermal power supplied by the production unit. Moreover, the temperature data, acquired by a meteorological station located close the area interested by the district heating, are available for the period 01/01/2003 to 30/04/2004. Starting from these data it's possible to assess the mean external temperature. The surveys of the thermal power generated and the fuel consumption for all the monitoring period, were gathered on a particular residential building fed by natural gas, chosen as the typical user in the period 10/11/2003 to 17/11/2003, with an acquisition frequency of 1 min for all the measurements. On the basis of the supplied data the generation efficiency equal to 82.8% was obtained.

To investigate the correlation between thermal power and external temperature, a parameter called ''Grado Giorno'' (''Deegre Day'', DD) was introduced. It is defined, in reference to the italian DPR 26 agosto 1993, n. 412, as the difference between 20 °C and the mean daily external temperature according to expression (1):

$$\mathrm{DD} = 20 - T_{me} \tag{1}$$

Consequently the correlation is true:

$$Q = \mathrm{DD} \times C \tag{2}$$

where Q is the energy needed to maintain an inner temperature of 20 °C in the building, and C is the global heat loss (kJ/°C)