Applied Thermal Engineering 44 (2012) 150–158

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Hospital CHCP system optimization assisted by TRNSYS building energy simulation tool

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ARTICLE INFO

Article history:
Received 31 October 2011
Accepted 1 April 2012
Available online 6 April 2012

Keywords:
Combined Heat Cooling and Power
Exergy analysis
Energy use in hospitals

ABSTRACT

The feasibility study of a trigeneration plant intended to integrate the existing natural gas fired-boiler central plant serving a 714 bed hospital located in Parma, North of Italy, is presented. The electric load and the heat load for both sanitary hot water and process steam are estimated on an hourly basis from the monitored actual consumption. The space heating and the cooling loads, instead, are computed, on an hourly basis, by the building energy software tool TRNSYS, version 16, by accounting for the actual climate of the considered location. The energy analysis points out that the Primary Energy Saving (PES) index is inadequate for sizing the Combined Heat and Power generation system (CHP). The approach based on the second principle of thermodynamics, instead, allows to identify its optimal configuration and size, i.e. Combined generation of Heat, Cooling and Power (CHCP) with prime mover overall nominal capacity equal or higher than about 7 MW. The economic analysis confirms that the maximum annual money saving occurs with trigeneration at a prime mover overall nominal capacity of about 7 MW. At higher values the operating financial budget deteriorates because of a too low electricity selling price. At the optimal economic condition the CHCP system simple payback period is of about 15 months. The national policies supporting cogeneration have a great effect on the results of the economic analysis and beyond them cogeneration may loose its economic appeal.

1. Introduction

Hospitals use a great amount of energy, both mechanical power and heat. Mechanical power, in the form of electric energy, meets lighting, technological plants and medical equipment operation requirement and space cooling needs as well. Heat is required for space heating needs, sanitary hot water and process steam production, for both laundry and sterilization purposes. In the hospital sector the energy load is continuous and nearly flat over the whole week. In fact many hospital activities continue day and night and also during the weekend. Furthermore, in hospitals frequently heat is needed at the same time as electricity and this good simultaneity between the electric and thermal loads is the best condition for consideration of Combined generation of Heat and Power (CHP). In addition, the self production of a significant part of the required electric energy improves the hospital electric power quality and reliability in case of grid outages. In Mediterranean climates a further chance is offered by absorption cooling which increases the heat demand, thus improving the overall heat recovery utilization and thus making electric and thermal loads more simultaneous. In this condition Combined generation of Heat, Cooling and Power (CHCP), i.e. trigeneration, can be more convenient than combined generation of heat and power only.

Medrano et al. [1] analyzed the potential for integration of Distributed Generation (DG) systems into commercial buildings in California. They concluded that hospitals represent the most compatible match of DG with heat recovery integration due to simultaneous and flat electric and thermal loads, and to a relatively low electric to thermal load ratio. Ruan et al. [2] discussed the optimal option of DG technologies for various commercial buildings, also including hospitals. Their results show that the hospitals are attractive for combined heat and power generation because of their stable thermal load demands and of a favourable heat-to-power ratio. They state that some DG technologies are more suitable for a certain type of building than others and then they note that in Japan gas engines, together with phosphoric acid fuel cells, are the prior order in selecting DG technologies for the hospitals. Arcuri et al. [3] applied a mixed integer programming model to the design optimization of a trigeneration plant for a hospital. They concluded that a trigeneration plant configuration utilizing heat pumps which are directly fed by a cogenerator, greatly improves energy management, achieving significant economic, energy and

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doi:10.1016/j.applthermaleng.2012.04.001