Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Energy 31 (2006) 490–515
ENERGY
www.elsevier.com/locate/energy

A new approach to exergoeconomic analysis and design of variable demand energy systems

E. Cardona*, A. Piacentino

DREAM—Department of Energetic and Environmental Research, Engineering Faculty, Università di Palermo, Viale delle Scienze, 90128 Palermo, Italy

Received 18 November 2003

Abstract

Exergoeconomics is an attractive research field regarding the optimisation of design and operability where complex energy systems are concerned. The different approaches to thermoeconomics can easily achieve optimal or near-optimal solutions for the design of energy systems in industrial applications, characterised by regular energy demand profiles; for applications in buildings, however, the great number of components operating at unsteady conditions due to the demand variability make these methodologies hard to use. Furthermore, in project phases of complex plants such as Combined Heat and Power (CHP) or Combined Heat Cooling and Power (CHCP), energy demand can be satisfied with different output shares among the various components. In this paper, a simplified exergo-economic methodology is presented, which is based on aggregate consumption data and on a case-oriented procedure for analysis simplification. A technique to internalise exergy flows between the considered energy system and other external systems is also introduced. The proposed approach was applied to a trigeneration plant serving a 300-bed hospital situated in a Mediterranean area; the obtained results were finally compared with the optimal solution previously determined by means of demand cumulative curves and plant running simulations.

* Corresponding author. Tel./fax: +39 91 236 113.
E-mail address: cardona@unipa.it (E. Cardona).

0360-5442/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.energy.2005.04.002

Nomenclature

TFA	thermoeconomic functional approach
$\mathbf{x}$	variables vector
F	cost function
$\mathbf{h}_\nu$	νth constraint equation
TEC	theory of exergetic cost
T_e	rated thermal recovery from the engine (kW_t)
C_a	rated cooling output from the absorption cooler (kW_c)
E_x	exergy entering the xth component, negative when exiting
H	heat exchange
h	specific enthalpy (kJ/kg)
T_0	environment temperature, dead state (K)
T	temperature (K)
S	entropy (kJ/K)
s	specific entropy (kJ/kg K)
p	pressure
I_k	capital cost of kth component
$\dot{I}_k$	annual cost of kth component (€)
D	yearly cost associated with a material flow (€)
d	specific cost associated with a material flow (€/kg)
$\bar{c}$	average unit cost of exergy content of a material stream (€/kJ_{ex})
$E_{tot,x}$	total yearly exergy content of xth material flow (kJ)
e	specific exergy content of a material stream (kJ/kg)
m	aggregate mass flow (kg)
H_{gas}	low calorific value of natural gas (kJ/N m^3)
c_F, c_F'	specific cost of natural gas burnt in the engine and in the auxiliary boiler respectively (€/N m^3)
c_P	specific heat at constant pressure
K_{air}, K'_{air}	air excess index respectively in engine and auxiliary boiler poor combustion
f	decision function
I	capital cost of a component (€)
$\bar{c}^W_{grid}$	average specific cost or revenue respectively when $N(T_e,C_a)>0$ or $N(T_e,C_a)<0$
WAUEC	weighted average unit exergy cost

Greek letters

Γ_r	function of r-component capital cost and its Lagrange multipliers, defined in [4,10]
β	capital recovery factor
λ_i	percentage of maintenance and operation cost for the ith component
Ψ_{LT}	low temperature factor, ratio between Low Temperature and High temperature heat recoveries from engine work
α_{stoich}	stoichiometric ratio between combustion air and natural gas
μ_{tower}	specific evaporating air flow (N m^3/kW h_c)