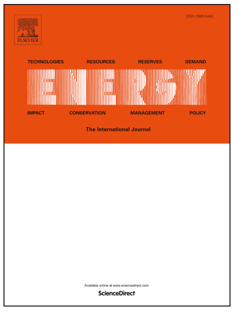
Accepted Manuscript



Optimal operation and marginal costs in simple trigeneration systems including thermal energy storage

Eduardo A. Pina, Miguel A. Lozano, Luis M. Serra

PII: S0360-5442(17)31097-6

DOI: 10.1016/j.energy.2017.06.101

Reference: EGY 11109

To appear in: *Energy*

Received Date: 6 May 2017

Accepted Date: 18 June 2017

Optimal operation and marginal costs in simple trigeneration systems including thermal energy storage

Eduardo A. Pina, Miguel A. Lozano, Luis M. Serra

GITSE – Aragon Institute of Engineering Research (I3A), Department of Mechanical Engineering, Universidad de Zaragoza, Calle María de Luna 3, 50018, Zaragoza, Spain

Abstract

The development of high-efficiency energy systems is a pressing issue nowadays, motivated by economic, environmental, and social aspects. Trigeneration systems allow for the rational use of energy by means of appropriate energy integration and provide greater operational flexibility, which is particularly interesting for buildings, often characterized by variable electricity, heating, and cooling demands. The benefits of trigeneration systems can be enhanced by the incorporation of thermal energy storage (TES), which decouples production and consumption. This paper analyses the operation of a simple trigeneration system including TES. The optimal operation is obtained by a linear programming model that minimizes the total variable cost. A thermoeconomic analysis based on marginal cost assessment of the internal flows and final products of the system is carried out, allowing to explain the optimal operation of the system and the role of the TES in achieving the optimal solution. The analysis unravels the marginal cost formation process, presenting a clear route from the final products obtained to the resources consumed. This information can aid the design of new plants, the retrofit of existing ones, and the operational management to achieve the minimum operational cost.

Keywords: marginal costs, operational strategy, thermal storage, thermoeconomics, trigeneration.

1 Introduction

Sustainability-related issues, such as the efficient use of energy, the depletion of fossil fuels resources, and the increase in greenhouse gas emissions, have become ever-present themes in the design of energy systems over the years. Energy process integration not only leads to higher energy efficiency, but also reduces environmental burdens and the economic cost of the final products [1,2].

The combined production of two or more energy products from the same resource, as a result of appropriate energy integration, is a defining characteristic of polygeneration systems. Cogeneration, or Combined Heat and Power (CHP), has been successfully applied in the industrial sector for decades. The building sector accounts for 40% of the total energy use in the European Union [3]. By combining cogeneration with thermally activated technologies, such as absorption chillers, the thermal coverage can be extended to meet refrigeration demands. There is a large potential for trigeneration systems (or Combined Cooling, Heat, and Power – CCHP) in the building sector, for example of countries in the Mediterranean area. In fact, the European Commission's Energy Performance of Buildings Directive [3] recognizes cogeneration as a strategic technology to contribute towards reducing energy dependency.

In the design of trigeneration systems for buildings, two fundamental issues must be addressed [4]-[6]: (i) the synthesis of the plant configuration (installed technologies and capacities); and (ii) the operational planning (strategy concerning the operational state of the devices, energy flow rates, purchase/selling of electricity, etc.). For existing plants, the only concern is the operational planning; however, in the case of new plants, the design procedure is more complex because of the wide variety of commercially available technologies, the variability of energy demands (hourly and monthly), and the fluctuations in energy prices [7,8]. A common approach to this problem is the single objective model aimed at identifying the minimum cost as the objective function. The reviews of [9,10] gather the characteristics of the optimization methods for polygeneration systems presented in recent publications, indicating the time scale, the objective function, and the solution method employed.

Thermal energy storage (TES) is playing an increasingly important role in the design of polygeneration systems, as demonstrated by several works [11]–[15]. As discussed in [16,17], the incorporation of TES