Multi-objective optimization of a trigeneration plant

K.C. Kavvadias*, Z.B. Maroulis

School of Chemical Engineering, National Technical University of Athens, Zografou Campus, 15780 Athens, Greece

ARTICLE INFO

Article history:
Received 29 June 2009
Accepted 21 October 2009
Available online 18 November 2009

Keywords:
Pareto
Genetic algorithm
Operation strategies

ABSTRACT

A multi-objective optimization method was developed for the design of trigeneration plants. The optimization is carried out on technical, economical, energetic and environmental performance indicators in a multi-objective optimization framework. Both construction (equipment sizes) and discrete operational (pricing tariff schemes and operational strategy) variables were optimized based on realistic conditions. The problem is solved using a multi-objective evolutionary algorithm. An example of a trigeneration system in a 300 bed hospital was studied in detail in order to demonstrate the design procedure, the economic and energetic performance of the plant, as well as the effectiveness of the proposed approach even under fluctuating energy prices.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Combined generation of different kinds of energy has become a mainstream application of distributed generation during the last decades. The proven advantages of cogeneration technology made it useful firstly in large-scale industrial plants and later on commercial or even resident buildings. Most recent advances, allow the investment of trigeneration systems that produce electricity, heat and cooling, utilizing the primary energy of a fuel even more efficiently, economically, reliably and with less harm to the environment than centralized dedicated production (Wu and Wang, 2006).

Trigeneration system design aims at the determination of the sizing and operational variables involved by optimizing a suitable criterion. Of course, the proposed designed solution must be subject to the restrictions fixed by the legislation, while it is very sensitive on the country’s energy policy and on wider geopolitical facts (i.e. abrupt oil price change). Optimization based on economical criteria from the investor’s point of view, has been studied thoroughly for both cogeneration and trigeneration plants (Chicco and Mancarella, 2005; Arcuri et al., 2007; Badami et al., 2008; Sanaye et al., 2008). Energy savings and environmental benefits of trigeneration system have also been discussed and proven to be important (Cardona and Piacentino, 2003; Chicco and Mancarella, 2007a, b).

However, the increasing need for more efficient systems that are both economically attractive and friendlier to the environment request the development of new criteria and determine new design rules. Economic performance, energy savings and emission reduction can be formulated by using indices that compare the benefits of trigeneration with energy production by conventional means. It is obvious that the design of such a system is associated with the above conflicting objectives. The use of a single-objective function, which is usually a weighted combination of several objectives, does not facilitate the judgement of the decision maker as it is often difficult to interrelate several objectives of different natures properly. Moreover, it is often wrong to claim that there is only one optimal solution because the trade-offs between conflicting objectives are important. Assuming so, certain optimal solution may be lost since they may never be ‘explored’ (Deb, 2001). On the contrary, with the use of multi-objective techniques a set of several non-dominated optimal solutions is obtained, also known as Pareto optimal set. As a result, the solution is not a single mathematically figure but a set of efficient solutions that can be examined using a judgment of the trade-offs involved, giving the decision-maker more flexibility.

On the basis of the above, trigeneration system design is a complex multi-objective optimization problem involving an economic (net present value), an energetic (primary energy savings) and an environmental (emission reduction) objective function, as well as physical and capacity constraints derived from the mathematical model and the requirements of the decision-maker.

The scope of this work is to present a method of optimizing a trigeneration plant based on economical, energetic and environmental criteria. The full set of efficient optimal solutions is evaluated and the effect of optimal design variables on the characteristics of the system is studied for a typical hospital building.

2. System description

The trigeneration system consists of the following units:

- A prime mover, usually gas turbine, steam turbine or in smaller scales internal combustion engine, which is driven by natural gas. It produces electrical energy and cogenerated heat and represents the core of the plant.
2.1. Energy load profiles

Energy loads can be described precisely by taking into consideration the following parameters: seasonal variation which depend on ambient temperature, daily profiles as a function of the working schedule and day type, i.e. working or non-working day. Usually non-working day profiles are smoother, closer to base load and with less hourly variations. Historical energy data for at least a year are necessary for designing of a trigeneration plant.

2.2. Energy tariffs

Energy tariffs affect heavily a trigeneration investment. The optimal design must be adjusted and estimated according to the pricing policy applied, taking into consideration all pricing schemes available. A quick index that helps in the tariff selection process is grid utilization factor (UF). It shows by the percentage of the energy bought in each month in relation with the energy that could be bought on maximum load. An equivalent expression is the average power demand divided by the peak power on the same timeframe.

2.3. Operation strategies

Operation strategies that are used in distributed generation plants are part of the process control system, which is dependent on the following factors: demand for each kind of energy, prime mover nominal power, coefficients of performance and conversion factors for all energy conversions devices involved. In literature the most common kinds of cogeneration systems are designed by either covering a constant part of energy or by following the evolution the electrical (or heat) load (Chicco and Mancarella, 2006). However, conventional load following strategies cannot be applied successfully in a trigeneration system as they do not exploit all the benefits of the system. More specifically, in strictly heat demand following, the prime mover will always produce the heat needed, so there will not be any waste heat available to feed the absorption chiller.
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات