Thermal-economic design of a micro-gas turbine CHP system using a multi-objective optimization approach

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ABSTRACT

Micro Gas -turbines are addressed as an option for decentralized energy generation. The reasons behind the use of micro-turbines include the technologic maturity stage, multi-fuel capability, low emission levels, heat recovery potential, and need of minimal maintenance [1]. Therefore, optimization of such systems is of the greatest importance in the area of power generation. Combined heat and power (CHP) systems are considered the best option to produce both heat and power simultaneously due to increased efficiency and reduced energy cost.

In this paper, it is presented a multi-objective optimization of a micro gas turbine operating in cogeneration mode. The system aims to provide electric and thermal power to fulfil the energy demands for a reference case, which corresponds to block of apartments located in Portugal. This CHP system is composed of air compressor (C), combustion chamber (CC), an internal air pre-heater (IPH), a gas turbine (GT), and a heat recovery heat exchanger (WHE). Each component of the micro turbine cycle is modelled using the energy balances of the first law of thermodynamics. It is also proposed an economic model that defines the purchase cost of each system component. The cost equations include thermodynamic variables that directly affect the component cost and performance [2]. The mathematical model yields two non-linear objective functions: the minimization of the total purchase cost of the system and the maximization of the incomes from the system operation. This latter includes the revenues from selling the electricity to the grid and the avoided cost of natural gas that would be consumed by a full conventional system to produce the same amount of useful thermal energy.

The optimization problem was solved by NSGA II algorithm. The decision variables of this cycle are compressor pressure ratio (r_C), compressor isentropic efficiency (η_C), GT isentropic efficiency (η_T), CC inlet temperature (T_3), and turbine inlet temperature (T_4). All the decision variables were bounded with upper and lower limits. In order to give physical significance for the results, several non-linear constrains were includes in the model. Those constrains concern the temperatures evolutions according to the thermodynamic cycle.

In multi-objective optimization, a decision-making process for the selection of the best optimal solution from the obtained Pareto frontiers is required, and this process is based on pair-wise solutions comparison.

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