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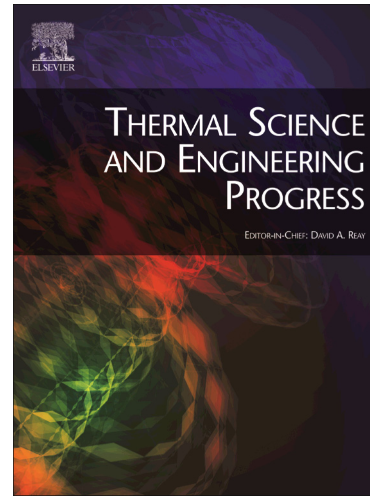

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Dynamic analysis of HVAC systems for industrial plants with different airflow control systems

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ABSTRACT

The aim of the present work is the analysis and optimization of HVAC control systems for environments under controlled thermo-hygrometric conditions in order to minimize energy consumption costs. A predictive mathematical model for the analysis of such systems has been validated in order to study the thermodynamics of conditioning processes for controlled microclimates. The model provides the hourly energy performance of an HVAC system by considering outside weather conditions. Based on such a simulation model, two different control systems have been implemented. Specifically, the first system is based on an adjustable airflow rate, whereas the second one on an adjustable inlet temperature of the controlled environment with a user-defined airflow rate profile. Both models estimate the energy consumption in terms of heating/cooling, humidification/dehumidification energy, reheat (when such process occurs) and electrical power demand due to fans and extractors. The results obtained with the two models have been compared under several climatic and set-point (comfort) conditions, thus assessing that the second control system with a minimum value of the airflow rate is the most efficient choice in terms of hot water and electrical power consumption. On the other hand, the adjustable airflow rate control system guarantees the comfort conditions for the whole microclimate.

Keywords: HVAC, Control Systems, Dynamic simulation, Microclimate, Energy efficiency.

1. INTRODUCTION

The optimization of performance, in terms of energy consumption, of air conditioning systems for the attainment of specific thermo-hygrometric conditions in indoor environments is mandatory in order to minimize costs. In order to improve the energy performance of conditioning, a detailed analysis of the plant and of the different process parameters that affect its performance is required. Besides, the design of the system components should account for the reduction of pollutant emissions.

In the literature, several works are devoted to the analysis of building features and to the choice of the most appropriate conditioning system in order to obtain a significant energy saving. To this end, in [1] a new methodology has been developed to reduce investments and energy demand and to select the best construction materials. The authors apply their methodology to a building design by considering different climatic zones of Spain and several scenarios. Among the process parameters, the role of outside climatic conditions and their influence in the conditioning process of controlled microclimates have been considered in [2,3]. Specifically, in [2] the authors carried out an analysis of the building envelope performance, whereas in [3] a dynamic model has been employed to evaluate the energy consumptions of the air-conditioning system.

The performance of the overall system with specific operating conditions can be optimized by employing numerical algorithms, as shown in [4]. An interesting review of multi-objective methods applied to energy systems is given in [5], where evolutionary algorithms have been employed to a stand-alone hybrid renewable energy system. As far as control strategies of HVAC systems are concerned, an optimization methodology for heat system is developed and validated in [6]. The optimization process is carried out by analyzing different control strategies. [7] pays close attention to air pollution emissions, specifically CO_2 concentration, dealing with control techniques. As regards the HVAC modes of operation, [8] deals with an optimization method that adjusts the most important process parameters in order to achieve the minimum energy consumptions by ensuring the thermal-hygrometric comfort at the same time. Some of the process parameters are the chilled water temperature and the supply air temperature and the authors are able to achieve a significant energy saving. Moreover, the optimization method takes into account both water side and air side consumptions. The proposed algorithm, named REA (Robust Evolutionary Algorithm), is further investigated in [9] in order to show its efficiency and effectiveness for HVAC energy management.

Controlled microclimates require specific comfort conditions, in terms of temperature and humidity, depending on the activities that take place within the conditioned environment. With this in mind, an important parameter to be considered is the intended use of the conditioned environment, as shown in [10,11]. Specifically, in [10] the authors propose different energy saving strategies applied to a conditioning plant for museums. The main purpose in these environments is to preserve the artworks which requires strict comfort conditions as regards the indoor air quality. The analysis takes into account also the presence of people in the environment. In [11], the focus of the work is energy saving with different set-point conditions strategies.

Another parameter to account for is the presence of people within the conditioned environment, since it changes the energy demand to satisfy the indoor comfort. As regards this issue, in [12], an interesting building HVAC control algorithm is developed by embedding an occupancy prediction model into the energy consumption control model. In details, this simulation model allows the minimization of the electrical power consumption by improving the indoor comfort at the same time, since it considers the occupancy level prediction for the environments. In [13], the thermal comfort of occupants by adopting different environmental control strategies is considered in office buildings placed in a humid subtropical climate. Specifically, the study