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Fuzzy logic controller implementation for a solar air-conditioning system

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Abstract

The implementation of a variable structure fuzzy logic controller for a solar powered air conditioning system and its advantages are investigated in this paper. Two DC motors are used to drive the generator pump and the feed pump of the solar air-conditioner. Two different control schemes for the DC motors rotational speed adjustment are implemented and tested: the first one is a pure fuzzy controller, its output being the control signal for the DC motor driver. A 7×7 fuzzy matrix assigns the controller output with respect to the error value and the derivative of the error. The second scheme is a two-level controller. The lower level is a conventional PID controller, and the higher level is a fuzzy controller acting over the parameters of the low level controller. Step response of the two control loops are presented as experimental results. The contribution of this design is that in the control system, the fuzzy logic is implemented through software in a common, inexpensive, 16-bit microcontroller, which does not have special abilities for fuzzy control.

Keywords: Solar air-conditioner; PID controller; Fuzzy logic controller; Microcontroller

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1. Introduction

Energy consumption in commercial and residential buildings represents approximately 40% of Europe's energy budget. The final energy consumption for 2002 in the building sector amounted to 435 Mtoe or 40.3% of the total EU-25 final energy use [1]. The higher living and working standards, the adverse outdoor conditions in urban environments and reduced prices of air-conditioning units, have caused a significant increase in demand for air conditioning in buildings, even where there was hardly any before. The number of installed air-conditioning systems in Europe with cooling capacity over 12 kW has increased by a factor of 5 in the last 20 years [2]. Total air-conditioned floor space has grown from 30 million m^2 in 1980 to over 150 million m^2 in 2000. Annual energy use of room air conditioners was 6 TJ in 1990, 40 TJ in 1996 and is estimated to reach 160 TJ in 2010. As a result of the projected world energy shortage, the use of solar energy for environmental control is receiving much attention in the engineering sciences literature. With suitable technology, solar cooling can help alleviate the problem. The use of solar power instead of electric power in air conditioning systems is gaining increasing interest during the last years. The trend towards reusable energy sources is a significant reason for this interest and especially for hybrid (solar-electric power) systems. The fact that peak cooling demand in summer is associated with high solar radiation offers an excellent opportunity to exploit solar thermal technologies that can match heat-driven cooling technologies. Of particular interest are urban areas where adverse outdoor conditions, as a result of higher outdoor pollution and the urban heat island effect, encourage the use of mechanical air-conditioning with a direct impact on peak electrical energy use [3]. Commercial application of solar energy for air conditioning purposes is relatively new. Lamp and Ziegler [4] give an overview of the European research on solar-assisted air conditioning up to 1996. Tsoutsos et al. [5] present a study of the economic feasibility of solar cooling technologies.

Different heat-driven cooling technologies are available on the market, particularly for systems of above 40 kW, which can be used in combination with solar thermal collectors. The main obstacles for large-scale application, beside the high first cost, are the lack of practical experience and acquaintance among architects, builders and planners with the design, control and operation of these systems. For smaller scale systems, there is no market available technology. Therefore, the development of low power cooling and air conditioning systems is of particular interest [6].

However, operating this type of system presents certain particular issues that must be addressed by the control strategy. Firstly, the primary energy source (the sun) cannot be manipulated, as in the case of any other conventional thermal process. Secondly, great disturbances exist in the process, mainly due to changes in environmental conditions. There are also dead-times related to fluid transportation which are variable depending on the operating conditions. Finally, the cooling demand is variable since it depends on the occupancy rate and the kind of activity that is being carried out in the cooled space. Several control strategies have been tested at solar power plants to address these problems [7–9]. Model predictive controllers have also received a lot of attention in the last few decades, both within the research control community and in industry [10]. The basic idea is to calculate a sequence of future control signals in such a way that it minimizes a multistage cost function defined over a control horizon.

In the recent years, the development of sophisticated control systems which are often including standard processors: microprocessors (μP), microcontrollers (μC), digital signal