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A distributed MPC strategy based on Benders' decomposition applied to multi-source multi-zone temperature regulation

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ABSTRACT

This paper presents a distributed model predictive control (DMPC) algorithm based on Benders' decomposition for temperature regulation in buildings using multiple heating sources. It is well known that the main objective of this control problem is to minimize the heating energy bills while maintaining a certain indoor thermal comfort. To reduce the heating costs, many buildings are equipped with different heating sources. An example is the use of a hot water based central heating system and local electric convectors as complementary heating sources. Using a linear system model of the controlled process, the MPC optimization problem can be solved by linear programming. In order to reduce the computational demand required to solve the minimization problem, the authors propose a DMPC algorithm based on the Benders' decomposition. The effectiveness of the proposed approach compared to the currently used PI-based control is illustrated in a simulation study.

1. Introduction

1.1. Global context

Nowadays the optimization of the energy consumption is a world target and it is no longer feasible to design a system without considering it. Within the services and households sector, the major energy consumer is the heating/cooling system (more than 50%), which means about 23% of the total energy consumption in European Union [1]. Even if the new trends are to construct buildings to accomplish new environmental standards, the problem remains unsolved for buildings where thermal insulation works are difficult. A solution to reduce the consumers' energy bills is the use of multiple heating sources. One of the most common examples, which will be our case study in this paper, is the use of a central gas or oil heating system as the base heating source and local electric convectors as complementary sources, in order to take advantage of the lower price of the kWh of the fossil fuels and in the mean time to use the faster dynamics of the electrical heating systems to ensure good control performances. To efficiently control these two types of heating sources an optimal control law is required. This is the context in which the presented work takes place.

1.2. MPC choice justification

Even if many studies were performed in order to optimize the energy efficiency of heating systems, the controllers that are mostly used today remain the on/off and PID. To ensure a proper regulation, auto-tuning methods of PID parameters have been proposed in [2,3]. Other approaches can be found in the literature like fuzzy logic [4], neural networks [5] or genetic algorithms [6]. To the authors' knowledge, studies on control strategies for multiple heating sources are almost inexistent.

During the last two decades a growing interest has been granted to model predictive control (MPC) due to its ability to handle constraints in an optimal control environment. In MPC, the control input is calculated by solving an optimal control problem (minimization of a cost function) over a given horizon. Only the first element of the open-loop command sequence is applied to the system. At the next instant, a new optimization is performed based on current measurements. The predictive control has been successfully used in many and varied applications [7–9]. In particular, for heating and cooling systems, different formulations of cost functions and constraints have been analyzed in [10] to minimize the energy consumption or to guarantee a desired comfort level. In [11] the authors compared a combination between a feedback linearization technique and a standard MPC approach with a nonlinear predictive controller for a temperature regulation problem in greenhouses. A stochastic predictive control approach applied on a room temperature regulation problem is proposed in [12] handling with chance constraints.

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