Control of HVAC Systems in Sweden: Current Status and Future Directions

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Abstract: Heating, Ventilation and Air Conditioning (HVAC) systems are used to maintain desired indoor comfort levels in the built environment against the effects of disturbances such as weather conditions and internal loads. Since these disturbances are in general predictable and buildings have thermal mass, implementing model predictive control strategies can lead to energy- and cost-efficiency. The automatic control group at KTH has developed novel HVAC control techniques and an advanced HVAC testbed where experimentally to test and evaluate innovative control strategies. The control approach proposed in the KTH HVAC testbed is stochastic and predictive, aiming to account for the intrinsically probabilistic nature of the comfort levels constraints of environments conditioning problems. This gained knowledge is now constituting a preliminary step from which it is possible to expand the research efforts to other air conditioning domains, specially datacenters.
In this abstract we describe the current work in the KTH HVAC testbed and outline the future research directions.

1. CURRENT STATUS

Buildings are estimated to account for about 40% of the final global energy use International Energy Agency (2011). At the same time, potential CO_2 emissions reductions enabled by using Information and Communication Technology (ICT) in HVAC schemes have indeed been estimated in 22% The Climate Group (2008), and potential energy savings enabled by applying demand-response strategies to non-residential buildings between 5% and 30% BSI (2008).

Aware of these figures, the automatic control group at KTH has been working on the problem of controlling HVAC systems (Parisio et al., 2013a, 2014a, 2013b, 2014b; Ebadat et al., 2013). The efforts produced a dedicated testbed, which is hosted in one of the buildings in the KTH campus. The testbed comprises advanced sensing and actuating capabilities, and is located in the ground floor of a seven-story office building and consists of four rooms: a laboratory and three student rooms. All the rooms are equipped with a Building Automation System (BAC) (Supervisory Control And Data Acquisition (SCADA) and Programmable Logic Controllers (PLCs)), a wireless sensor network, an actuator network and a weather station, which allow to monitor continuously the status of the system (e.g., CO_2 levels, temperatures, humidity, external weather conditions).

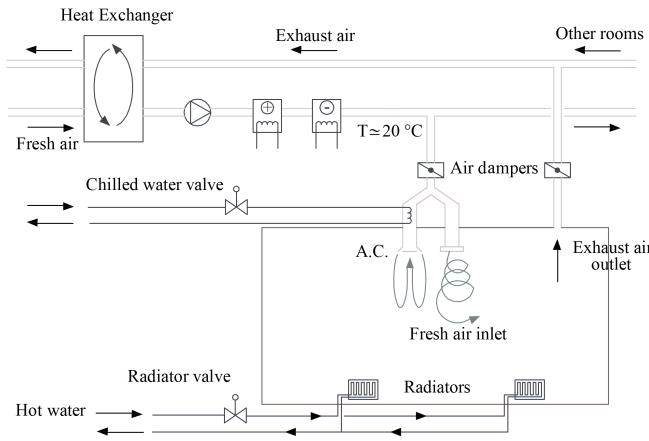

Fig. 1. Scheme of the HVAC system of the testbed.

As schematized in Figure 1, the HVAC system of the testbed is composed mainly of a ventilation system, supplying fresh air, and a radiator heating system. Figure 2 depicts the architecture of the control system implemented in the testbed. The indoor temperature and air CO_2 concentration levels (both to be considered as comfort indicators) are controlled through the ventilation system and radiators, which are actuated using low-level proportional-integral controllers. The set-points for the low-level controllers are computed by a novel Scenario-based Model Predictive Control (SMPC) strategy at each time instant, based on new measurements and updated information about weather and occupancy patterns.

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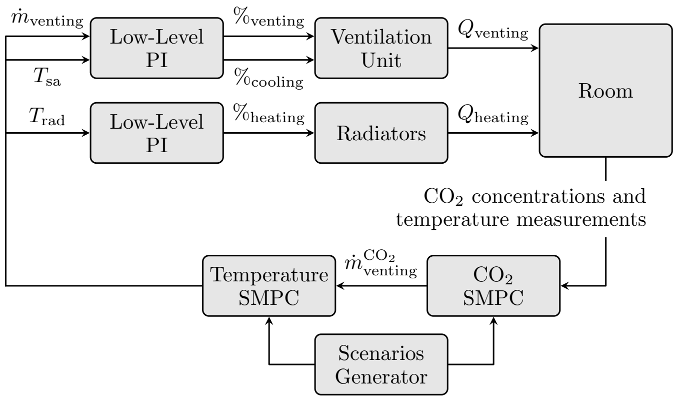

Fig. 2. Architecture of the control system implemented on the testbed.

Since it is possible to assume the possibility of violating the comfort bounds on the indoor temperature and CO_2 levels with a predefined probability, SMPCs can then be formulated so that they can simultaneously incorporate weather and occupancy forecasts and their uncertainties by means of probabilistic constraints. The probabilistic constraints can then be approximated by means of randomized techniques to yield an SMPC which is solvable by using standard techniques.

The testbed is in the near future being replicated in Luleå Tekniska Universitet, where the plans are to instrument the whole corridor and rooms hosting the personnel of the automatic control group.

2. FUTURE DIRECTIONS

The control of HVAC systems for buildings is one example of a broader world of conditioning necessities. We here drive the attention to the following (in our opinion) important applications:

Collaborative HVAC schemes for networks of buildings the built environment comes with an intrinsic thermal inertia. If opportunely exploited, the joint coordination of networks of buildings can have a sufficiently big impact to be considered an influential player in a smart grids scenario: indeed it is possible to implement effective demand-response strategies and achieve higher common goals like load shifting and peak shaving.

HVAC schemes for networks of datacenters our ICT-based society is requiring more and more computational capabilities, naturally provided by datacenters. These environments transform electrical energy into information, and eventually produce heat that has to be removed. Figures indicate that in standard datacenters approximately 50% of the consumed energy is dedicated to HVAC purposes.

It does not surprise that actually Sweden is a natural choice for companies like Facebook: Luleå, for example, hosts the European servers of several big companies (Facebook included). The reason is that the cold and dry Nordic climate, among with the relatively low price for the electrical energy, makes the air conditioning economically advantageous.

This constitutes an opportunity: datacenters, differently from buildings, can shift their internal loads both in space and in time, and this feature enable possibilities that are perfectly suited for automatic control community.

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