POPULAR SCIENTIFIC ABSTRACT

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Analysis and Application of Model Predictive Control in Energy Systems

Greenhouse gas emissions are the primary factors causing climate change and global warming, wherein around three quarters of total greenhouse gas emissions are attributed to energy-related activities. This highlights the significance of improving energy efficiency to achieve carbon neutrality and sustainable development. Advanced control strategies can facilitate the energy-efficient/cost-effective operation of energy systems. Model predictive control (MPC), a popular advanced control algorithm, has received a lot of attention and demonstrated excellent control ability in various applications.

In light of the inherent diversity and complexity of thermal energy systems, the application of MPC in thermal energy systems of different types and scales should be examined to fully exploit its potential benefits. This thesis aims to identify and demonstrate how MPC can enable energy-efficient/cost-effective operation of thermal energy systems at different scales. To achieve this, numerical experiments of MPC on different case studies were carried out. Given that the share of greenhouse gas emissions from buildings and industry sectors in total greenhouse gas emissions is nontrivial, the thesis focuses on three case studies consisting of buildings, PCM-based ventilation systems, and greenhouse energy systems. The selected case studies cover thermal energy systems at building room level, heating, ventilation and air conditioning component level, and relatively large industry level.

To reach the aim of the thesis, dynamic simulation models of different case study thermal energy systems are first developed to analyze energy production, storage, and consumption. Next, MPC for different thermal energy systems is implemented using diverse control models and tool-chains to demonstrate its feasibility and applicability. Then, a rule-based controller (RBC) for each thermal energy system is proposed and simulated to benchmark and manifest the benefits of MPC. Last, sensitivity analysis is conducted considering various disturbances such that the robustness of the developed MPC is evaluated and the limitations are highlighted.

With a systematic investigation of MPC on three thermal energy systems at different scales, a comprehensive conclusion is made. In short, the feasibility of applying MPC for different thermal energy systems to improve energy efficiency and reduce operational costs is examined, identified, and demonstrated. The evaluation results highlight the influence of the MPC setups and disturbances on the control performance. Also, MPC exhibits limitations and it does not necessarily outperform RBC. The benefits of MPC compared to RBC highly depend on the setups for both MPC and RBC as well as the evaluation metrics.