Modeling the nonlinear temperature response of district heating systems for model predictive control applications

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Abstract

State-of-the-art methodologies for the optimal operation of district heating systems use model predictive control. These methodologies thus necessitate an appropriate model representing the temperature dynamics of the distribution network. Accurate forecasts of water temperature at critical points of the network that would be obtained by employing such model are crucial for meeting constraints related to consumers while minimizing the production costs for the heat supplier. A new approach to the modeling of the temperature dynamics in district heating networks is proposed in the paper. It is based on conditional Finite Impulse Response (cFIR) models, i.e. for which model coefficients are replaced by coefficient functions of some explanatory variables. Such an approach permits to capture nonlinear variations of the time-delays in the network. In the present case, the two explanatory variables are the water flux at the supply point and the time of day. In order to estimate the coefficient functions in a nonparametric fashion, local polynomial regression is employed. Coefficient functions are also allowed to vary in time, thus permitting to track long-term variations in the characteristics of the process considered. For that purpose, the coefficient functions are recursively estimated by minimizing a Least-Square type objective function, including an exponential forgetting scheme and a regularization term. Results are given for the test case of the Roskilde (Denmark) district heating system over a period of more than 6 years. The advantages of the proposed forecasting methodology in terms of a higher forecast accuracy in comparison to existing ones, its use for simulation purposes, or alternatively for better understanding transfer functions of district heating systems, are clearly shown. Integration of this new type of nonlinear modeling approach in model predictive control methodologies is discussed.