520e Generic Procedure for Data-Driven Predictive Modelling for Control - Exemplified on a Cement Kiln

Bao Lin, Bodil Recke, Torsten Vagn Jensen, Jørgen Knudsen, and Sten Bay Jørgensen

This paper presents a generic procedure for development of data-driven models. A first principles model (FPM) is desirable for designing effective control systems. However, a fundamental FPM is probably difficult to validate due to the complex kinetics and limited operational measurements. Data-driven approaches therefore provide a viable alternative.

The generic data-driven modelling procedure consists of the following three steps. The objective of the first step is to define an optimal plant operation mode by performing a model and control analysis. Basic system information, including the operating window and characteristic disturbances, as well as fundamental knowledge of the control structure, such as degrees of freedom of and interactions between basic control loops, will be obtained. The second step identifies a predictive model using data-driven approaches. A suitable model structure will be proposed based on the extracted process dynamics from operating data, followed by parameter estimation using multivariate statistical techniques. Dynamic partial least squares (PLS) approach solves the issue of auto-correlation. However, a large number of lagged variables are often required that might lead to poorly conditioned data matrices. Subspace model identification (SMI) approaches are suitable to derive a parsimonious model by projecting original process data onto a lower dimension space that is statistically significant. In case a linear model is not sufficient due to strong nonlinearities, neural networks (NN) provide a possible solution. The third step is model validation. Independent operating data sets are used to verify the prediction ability of the derived model.

The proposed framework is applied to develop a predictive model for a cement kiln system, which is the most energy-intensive equipment in cement plants. Many different waste materials are increasingly burned in cement kilns to save non-renewable fossil fuels. Switching between different fuels may represent a major process disturbance. Hence, there is a significant interest in stabilizing the kiln operation through suitable multivariable control. A predictive model of cement kiln is developed to firstly stabilize the operation, and secondly to investigate optimizing control. Linear models obtained with numerical subspace state space system identification (N4SID) and canonical variate analysis (CVA) are compared to a nonlinear state space neural network (SSNN) model. The reliability and viability of each modelling approach will be investigated on process data from cement plants. After validating the identified model on operating data, the predictive model will be applied to design a control system for stabilizing and possibly optimizing kiln operation.