Real-Time Substrate Feed Optimization of Anaerobic Co-Digestion Plants

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Part II

Substrate Feed Control for Biogas Plants

Introduction

In this part of the thesis the fourth component of the developed dynamic real-time substrate feed optimization, introduced in the introduction of Part I, is discussed. This fourth component is the dynamic process model of the controlled biogas plant.

“There is a general agreement in the literature that the application of mathematical models is a prerequisite to improve digester performance” (Dewil et al., 2011). There are various models of the anaerobic digestion process, from very simple ones to very complex models with a lot of equations. So far, only simple models are used for feed control of biogas plants. On the one hand, stability of model-based controls cannot be shown if complex models are used and on the other hand doing simulations with the complex ones in real-time is not yet possible. Furthermore, state and parameter estimation schemes for simple models can be developed more easily. In RTO a complex model may be used, because it has not to be solved in real-time. Therefore, the developed model is a very complex one, such that optimization runs performed in the RTO scheme yield realistic optimal solutions.

To the authors knowledge RTO has not been applied to substrate feed control for biogas plants before. The works of my colleague Christian Wolf (Wolf et al., 2009, Wolf, 2013) and similarly Ziegenhirt et al. (2010) can be seen as predecessors of this works. They focus on feed optimization of biogas plants using methods from evolutionary computation as well. In contrast to this thesis they do not close the loop, but apply the optimal substrate feed in an open loop manner.

Before the model is described in detail in Chapter 7 the anaerobic digestion process is briefly introduced in Chapter 5. An extensive review of published control methods applied to anaerobic digestion processes is given in Chapter 6.

General Remark on Notation

To keep the text readable, in the following the mathematical notation in this part of the thesis is relaxed a little bit. The basic idea is, that all physical, chemical, ... values and parameters x are a product out of a number $\{x\}$ and a unit $[x]$ as given in the following equation (5.0).

$$x := \{x\} \cdot [x] \tag{5.0}$$

Except stated otherwise all numerical values of x are real and positive numbers. Thus, in mathematical notation, all numerical values of x are element of the set of all real and positive numbers, thus $\{x\} \in \mathbb{R}^+$. Often x is dependent on time $t \in \mathbb{R}^+$, then the numbers are generated out of a time-dependent function: $\{x\} : \mathbb{R}^+ \to \mathbb{R}^+$. Whether x is constant or time-dependent should be clear out of the physical context. Because all such values x are measured in a unit $[x]$ be attentive when plugging the value x into an equation, because it has to be plugged in together with its unit. It is the task of the reader to check whether the units do cancel out. If they do not, appropriate correction terms have to be introduced, e.g. $3600\ \frac{\mathrm{s}}{\mathrm{h}}$.