MATLAB Toolbox for Biogas Plant Modelling and Optimization

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Introduction

Optimization, stability analysis and **control** of agricultural and industrial biogas plants become more and more important to achieve and guarantee sustainable efficient plant operation. One possible approach to address these challenging tasks is to develop detailed mathematical models as an approximation of real-world full-scale biogas plants. A combination of these models and sophisticated algorithms has proven to provide good solutions to the challenge of optimal plant monitoring, operation and control. To be able to do this in a well-structured manner a MATLAB® [1] toolbox has been developed for these purposes in particular. The models of the biogas plants as well as necessary optimization and control algorithms are developed in MATLAB/Simulink. Furthermore, graphical user interfaces (GUIs) for the user are created using MATLAB's GUI designer to offer best availability and useability to the user.

The Toolbox

The **key idea** of the toolbox is to treat algorithms for optimization and control and biogas plant simulation models separately. The advantage is that all algorithms can be easily applied to different tasks as well as different biogas plant models. As prerequisite all models have to be designed following the same guidelines, which are facilitated by using well-developed graphical user interfaces implemented in the toolbox. With these GUIs the user can e.g. specify the setup of a plant, like the number and properties of the fermenters as well as those for the cogeneration units available on the plant. Furthermore, physical and chemical characteristics of the substrate feed can be specified, which makes detailed simulations of various substrate mixtures possible. The toolbox then uses this information to semi-automatically generate a MATLAB/Simulink model of the specified biogas plant, which by default satisfies the required guidelines (see figure 1 for an example). The fermenters are modelled using the well-known **Anaerobic Digestion Model No. 1** (ADM1) [2], which is used to model the anaerobic digestion process of agricultural biogas plants, as it is done in [3, 4] respectively. The ADM1 is a structured model with disintegration and hydrolysis, acidogenesis, acetogenesis and methanogenesis steps, which is implemented in MATLAB in form of a differential equation system [2].

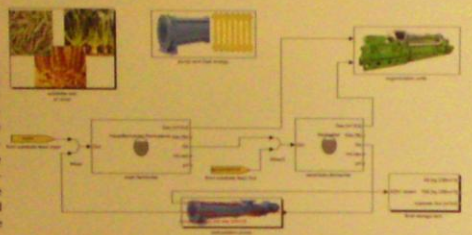

Figure 1: Example of a biogas plant simulation model containing two fermenters

Scope of Performance

The toolbox uses a generic optimization scheme to easily apply and adapt various optimization algorithms. Solvable optimization and optimal control problems using the toolbox are:

- **Calibration** of biogas plant models by comparing virtual and real measurements.
- Finding a constant substrate mixture leading to an optimal and stable long-term stationary operation of the plant (see figure 2).
- Finding an optimal operating point satisfying various constraints, such as pH value, FOS/TAC value, biogas production, methane content, etc.
- Determining an optimal control strategy leading to the obtained optimal operating point above or to find a better operating point as the current one using **Nonlinear Model Predictive Control** (NMPC) (see figure 3).

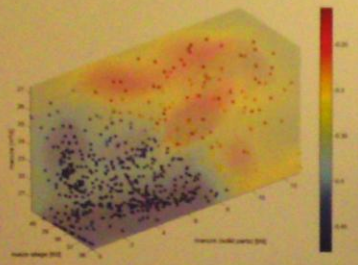

Figure 2: Overall goodness of the evaluated substrate mixes for optimal long term stationary operation (the smaller the value (the cooler the color), the better the result)

Conclusion

The goal of this toolbox is to optimize the operation of full-scale agricultural and industrial biogas plants and to analyse their operating point with respect to optimality and stability. Achieving this goal could lead to more profitable and therefore competitive operation of biogas plants, which will promote the role of biogas plants as energy source in the future. The result of the national research project MOBIO [5] demonstrates the applicability of this toolbox.

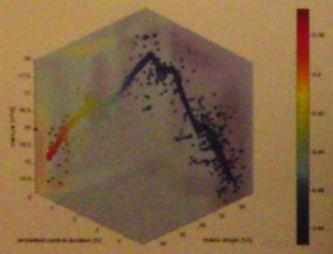

Figure 3: Overall goodness of the evaluated substrate mixes during the optimal control process using NMPC (the smaller the value (the cooler the color), the

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