DYNAMIC SIMULATION OF A BIOGAS PLANT PROVIDING CONTROL ENERGY RESERVES

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Introduction

The increasing integration of renewable energy sources leads to challenges for the power grid balance. The share of power plants with intermittent energy production is rising. The increasing volatility of supply and demand has to be compensated by more flexibility in the energy system. Plants that operate on biomass-based technologies, like biogas plants, have a high potential for producing energy on demand due to the almost infinite storability of the energy carrier. Heat and power can be produced flexibly at biogas plants by using CHP units.

In this work dynamic models for the simulation of flexible operation of an Austrian biogas plant with biomethane production using the process simulation tool IPSEpro are presented. Additionally the effects of providing positive secondary control reserves on the needed gas and heat storage capacities were investigated in a case study including ex-post simulations.

Model Development

IPSEpro version 7.0 was used to develop a model of the investigated biogas plant. The plant under investigation is a waste recycling plant with a yearly production of about 4.4 Mio. m³ biogas and an installed gas storage capacity of 4,800 m³. The plant's operation is currently designed to convert biogas to biomethane by a gas permeation process. Alternatively the produced biogas can be converted to heat and power by two CHP units with a total capacity of 1.36 MW. The developed simulation model is shown in Figure 1. The model bases on data that was collected during a one-year-monitoring in 2015. Additionally data from 2016 was used for the ex-post simulation described in this work. The two CHP units were modeled in more detail and are described afterwards, same as the newly developed model for dynamic simulation of the gas storage.

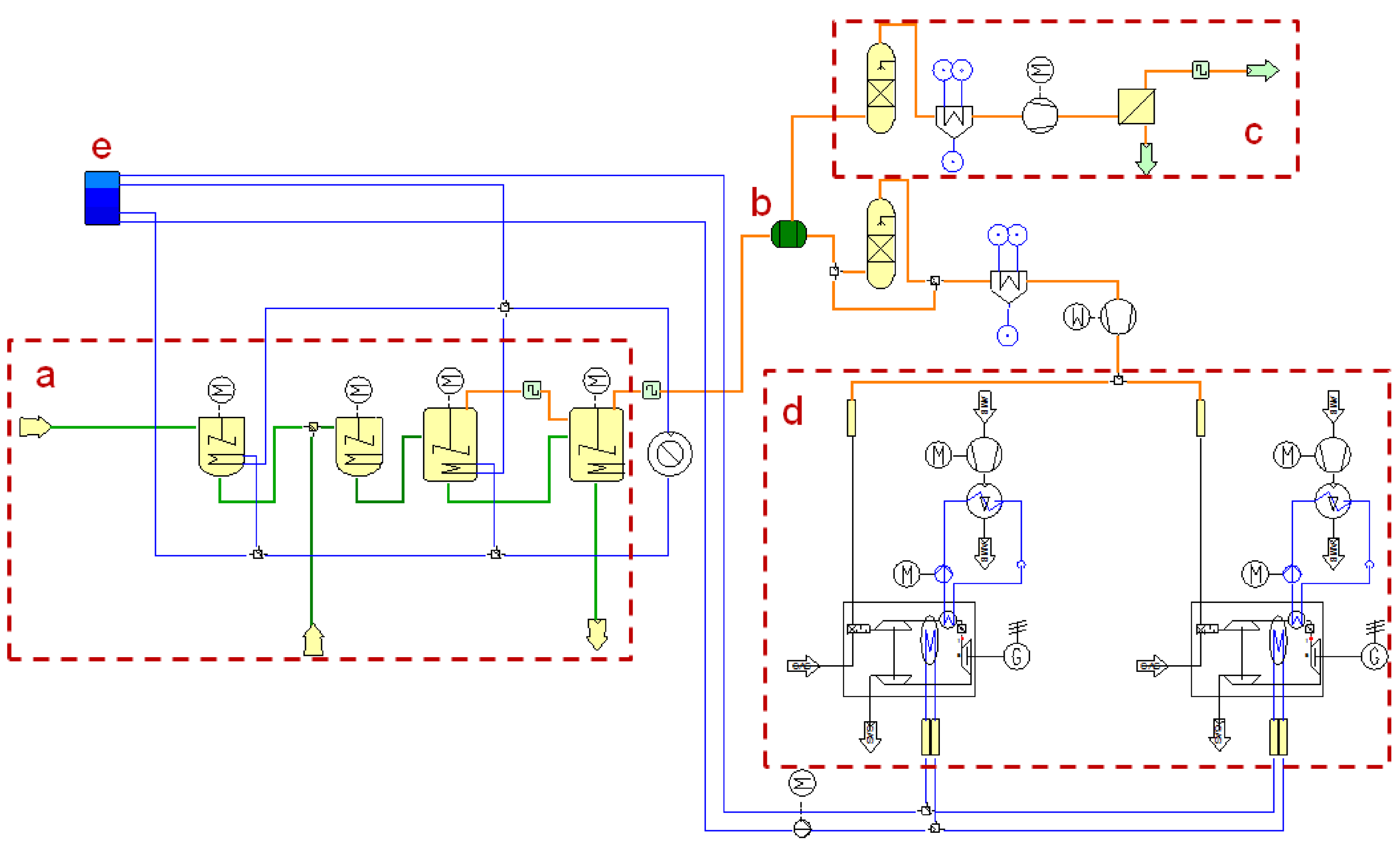

Fig.1: Flow sheet of the investigated biogas plant in IPSEpro (a…biogas production process, b…gas storage, c…gas upgrading, d…CHP units, e…heat storage)

For dynamic simulation of the biogas utilization a gas storage model was developed, with which the current gas storage level can be calculated and displayed. The stored biogas can either be directed to the gas upgrading or to the CHP units, in case of activation of control reserves. The volume flow V_{CH4} to the gas upgrading is held constant to $V_{N,}$ whenever the storage is not full and is increased to the flow of the incoming biogas V_{IN} if the storage is full. At the beginning of the simulation the gas storage level c was set to be half of the maximum level c_{max}.

$$c_0 = 0.5 * c_{max}, \qquad t = t_0 \tag{1}$$

$$\dot{V}_{CH4} = \begin{cases} \dot{V}_N, & c_{min} \le c \le c_{max} \\ \dot{V}_{IN}, & c > c_{max} \end{cases} \tag{2}$$

For the calculation of the produced heat and power a sound simulation model of the CHP unit is very important. Therefore a new CHP model was designed, implemented and tested in IPSEpro. The model is based on mass and energy balances. The electrical efficiency curve of the gas engine was implemented. This was done by defining the engine's power efficiency at three operation points (full-load, 75 % part-load and 50 % part-load). These operation points are also defined in the documentation of the CHP units and, therefore, other gas engines (brands and sizes) can be implemented easily. Between the defined points, a linear interpolation was done.

Case Study Parameters

One month of operation was simulated ex-post using the described model with providing positive secondary control reserves at a working price of 180 € MWh^{-1}. The month that was chosen for simulation was October 2016 since control reserves were activated very frequently during this period. The times of activation of control reserves were determined by evaluation of published data by the Austrian transmission system operator APG.

Additionally the heat production and heat demand curves were evaluated to determine the optimal heat storage size (hot water tank) and whether the investment in a storage is economic. The method used in course of the cost efficiency analysis was the annuity method

Results

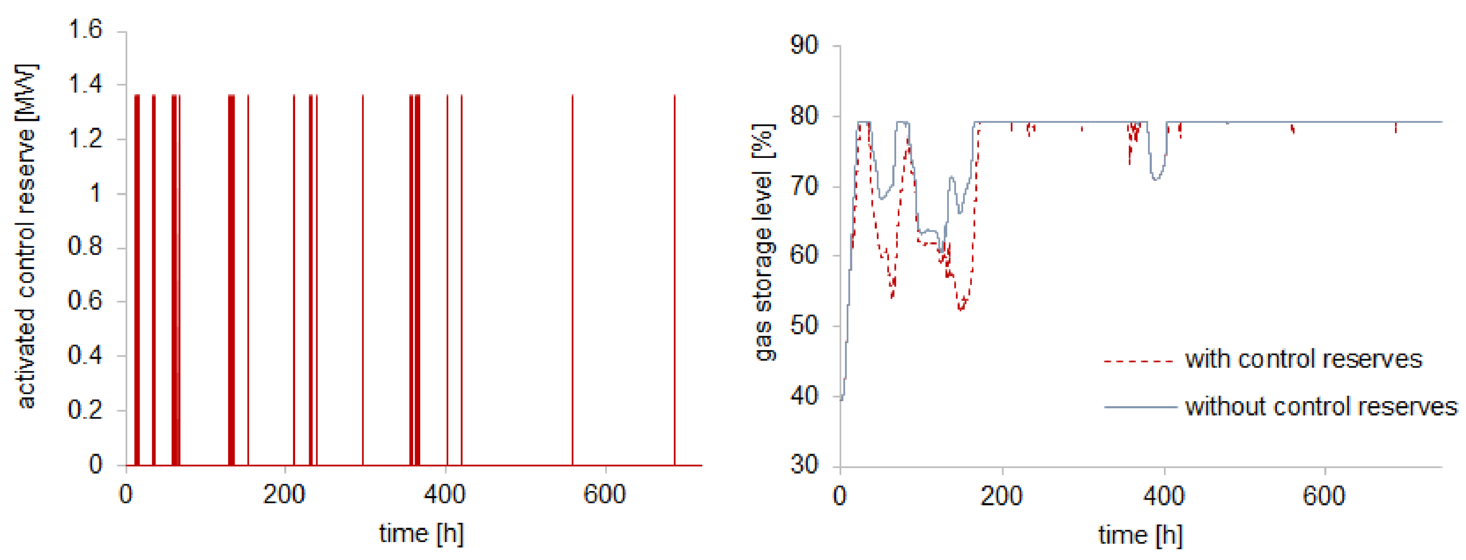

Figure 2: Times of activation of control reserves (left) and comparison of the gas storage level with and without providing control reserves (right)

The simulation results regarding the effects of providing control energy reserves on the gas storage capacity can be seen in Figure 2. In the left figure the times of activation of control reserves are shown. The right part shows the gas storage level during the simulated period while providing control reserves (dashed line) and without providing control reserves (solid line). The installed gas storage capacity of 4,800 m³ proves to be sufficient for providing positive secondary control reserves while processing at least 600 m³ h^{-1} biogas to the gas upgrading in the simulated period.

It is of high economic interest to utilize as much of the heat produced with the CHP units as possible. For this purpose a cost efficiency analysis on the basis of the annuity method was done to determine the optimal heat storage size for the investigated case. The results of the analysis are shown in Figure 3. In the left figure the profitability as a function of the heat storage volume is shown. A hot water tank with a volume of 10 m³ proved to be most economic with a profitability of 0.0038 and an annuity of 111.4 €. Additionally a sensitivity analysis of the two factors cost of external heat consumption and investment cost was done regarding a heat storage volume of 10 m³. The results are shown in the right part of Figure 4. It can be seen that higher investment or lower heat costs can lead to a negative profitability.

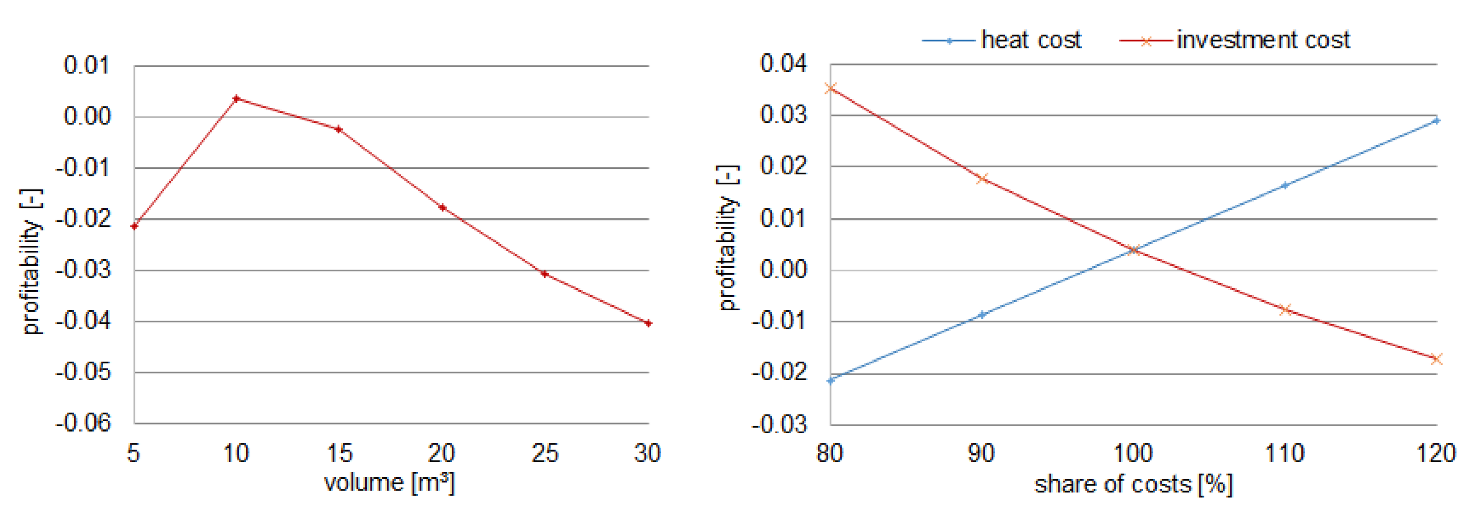

Figure 3: Results of cost efficiency analysis, profitability of different storage volumes (left) and sensitivity analysis regarding heat and investment costs (right)

Conclusion

A model for dynamic simulation of flexible operation of a biogas plant with biogas upgrading to biomethane was developed in the process simulation program IPSEpro and proved suitable. The results show that the installed gas storage capacity of 4,800 m³ proved sufficient to provide control reserves and biomethane simultaneously. The results of a cost efficiency analysis show that a volume of 10 m³ for a hot water tank heat storage proved most economic with an annuity of 111.4 €.

Acknowledgement

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