Scientific scientific and technical report – phase no. 2
Establishing of the functional structure of the biorefinary plant on the basis of HILS concept (Hardware in the Loop Simulations), the design of the pilot photobioreactor and the design of control algorithms validated on the mathematical model

Abstract

The phase 2 of the project No. 269/2014 – BIOCON (*Establishing of the functional structure of the biorefinary plant on the basis of HILS concept (Hardware in the Loop Simulations), the design of the pilot photobioreactor and the design of control algorithms validated on the mathematical model*) consisted in the achievement of seven activities as follows: *Establishing of the functional structure of the biorefinary plant on the basis of HILS concept* (activity 2.1), *Design of the photobioreactor for the photosynthetic growth of the micoalgae* (activity 2.2), *Design and configuration of the hardware control structure of the biorafinary plant according to the adopted operating structure* (activity 2.3), *Design of the human-machine interface system of the biorafinary plant according to the adopted operating structure* (activity 2.4), *Design and validation in numerical simulation regime of the fuzzy control of the biorafinary plant* (activity 2.5), *Design and validation in numerical simulation regime of the optimal control of the anaerobic digester and photobioreactor* (activity 2.6) and *Disemination of the results obtained in the project* (activity 2.7). **All the activities were fully achieved** and they have the role to prepare the phase no. 3 which provide the obtaining of experimental results using the pilot structure of the biorefinary plant (of HIL type) adopted within the project.

The activity no. 2.1 established a diagram of flows that are changed between the two interconnected components of the biorefinary plant of HIL structure. There are presented the chemical and biochemical processes that take place in both anaerobic digester and photobioreactor. It resulted an operating scheme that will be the basis of the experiments done in the phase no. 3 of the project. The activity no. 2.2 consisted in the design of the lab photobioreactor (the physical component of the HIL structure). Thus, a photobioreactor of rectangular shape was chosen having the useful volume equal to 5l. All the constructive elements of the photobioreactor's body were designed and sized. The transducers and actuators necessary for the developing and implementing the monitoring and control system of the photobioreactor were chosen. Within the same activity the lighting system for the microalgae growth was also designed. Within the activity 2.3 an interface system for acquisition and control functions of dSpace type was adopted. It allows the implementation of the monitoring and control functions on the basis of Matlab-Simulink schemes. These schemes are converted in the code corresponding to the dSpace system and run on-line on the dSpace interface. The computer on which the Matlab-Simulink programs and the HMI are running was also configured. Within the activity 2.4 the graphic interface – HMI for operating the biorefinary plant was designed. \the interface has been designed in ControlDesk medium and through the designed screens it offers the following facilities: visualization of numerical values of the variables of interest of the process, graphical plot aiming to observe the time evolution of the process variables, seting the setpoints, changing the parameter values during runtime of the application, storage the values of the process variables in view of further processing. The activity 2.5 approached the fuzzy control of photobiireactor. Thus a fuzzy control algorithm for the anaerobic digester was proposed and validated through numerical simulation. In the same activity two fuzzy control algorithms were

designed, one for the photobioreactor and one for the whole biorefinary plant. For this last step the effect of the photobioreactor connection with the anaerobic digester on the control loops was previously studied. The conclusion drawn from the activity 2.5 is that the incoming substrate (disturbance variable) has a reduced weight and a slow effect, while the influences produced by the dilution rate of the anaerobic digester have a high magnitude but they are very fast rejected. Within the activity 2.6 an optimal control algorithm of the extremum seeking type has been approached for the two components of the biorefinary plant. In both cases the performance indicators were defined (for the anaerobic digester three situation considering different performance indicators were treated: 1. the methan quantity produced in the digester, 2. the pollutant level to the digester output and 3. an agregated indicator. For the photobioreactor a performence indicator that consider the productivity and the cost of the electrical energy consumption has been adopted. The algorithm works properly, i.e. it alwais captures the point of maximum of the performance criterion but it has a major drawback: the searching time is big enough which makes it inadequate for an on-line control of the physical plant. As a consequence, different procedures was developed through which the photobioreactor extremal control is done indirectly by transforming the extremum search in a stabilization issue to an optimal setpoint. The optimal control of the whole process is done through the biomass control to an optimal setpoint using the dilution rate as control variable. To versions for obtaining the optimal regime of photobioreactor were established.

The results obtained in this phase of the project were diseminated through 10 scientific papers published in the proceedings of conferences indexed in international databases (IEEE xplore, Scopus). Because of the lack of space within this report it is available an extended RST on the project's site. It details each activity to the website address report phase2.

On the project's website could be also find a video presentation of HMI interface developed within activity 2.4 (video presentation).