SCADA System for Management and Visualization in Generation of Renewable Energy from Biomass

Mitko Gospodinov[1],
[1]Institute of Systems Engineering and Robotics,
Bulgarian Academy of Sciences,
Bulgaria

Evgeniya Gospodinova[2],
[2]Institute of Systems Engineering and Robotics,
Bulgarian Academy of Sciences,
Bulgaria

Krassimir Cheshmedjiev[3]
[3]Institute of Systems Engineering and Robotics,
Bulgarian Academy of Sciences,
Bulgaria

***Abstract* - In the paper is described the project of one of the first SCADA (supervisory control and data acquisition) system for biogas installations in Bulgaria. SCADA is a type of industrial control system (ICS) as computer-controlled system for monitoring and control of technological processes in biogas installations. Development of SCADA for `biogas plants is new scientific and industrial implementations of the remote process control and supervision in generation of renewable energy from biomass. The system is based on the programmable logic controllers (PLC) and human-machine interface (HMI). The system is designed for producing a huge volume of biogas, electricity and thermal energy with not very high amount of investment. The proposed system guarantees high reliability and productivity, low own consumption and modern monitoring and control of the technology parameters.**

Keywords- SCADA system, renewable energy, biomass, biogas, bioreactor, process control, process visualization.

I. INTRODUCTION

Generation of renewable energy from biomass (plant or animal organic waste substrates) is a modern way of complex solving a lot of problems for utilization of the biological waste, producing of electricity and thermal energy and achievement the aims of European Union (EU) for local energy independence and sustainable environment saving [1, 2].

The biogas technologies are unique because of obtaining the energy potential of wide spectrum organic waste. The effective products are: biogas, electricity, thermal energy, fertilizers, and carbon dioxide for industry.

Building of biogas installations allow achievement of relative energy independence of the regions and country as whole and implementation of the resolutions of EU member countries for increasing of renewable energy using and decreasing the carbon emissions [3, 4, 5].

Automation of the renewable energy generation processes is based on the precise supervision, control and management of the complete installation for producing of biogas, electricity and thermal energy. The control system has to provide permanent quality of biogas and electricity with reducing the influence of the personnel over the non-interruptible processes. The system of control and supervision is oriented at the minimization the personal faults.

The aim of the article is presentation of development of the intelligent SCADA system for supervision, control and maintenance of the biogas and electricity producing process, which is planned to be implemented in one of the first biogas plants in Bulgaria.

II. TASKS AND FUNCTIONS OF THE SCADA SYSTEM

The developed automated system for monitoring and process control for biogas and electricity through SCADA software is implemented on the basis of:

1. Programmable logical controllers. They have built three communications ports:
   - MPI port-used to connect to the control panel;
   - PtP port-communication port with RS485 interface;
   - Ethernet port-used to connect to the bioreactor and SCADA system.
2. The control panel has been designed with touch-screen monitor which is used for monitoring and management of the installation by the operator or automatically by the SCADA software.

The developed SCADA system is working in real time. The main tasks are:

1. Loading of input data and parameters of the technology process.
2. Data transfer of information between the devices, PLC and industrial computer via Ethernet and remote control via Internet.
3. Data archive in normal and emergency mode.

The SCADA system offers wide range of technical features as follows:

1. Connection of biogas and energy generating equipment in complete non interruptible process.

2. Centralized management system with minimal personnel.
3. Safety control of the equipment.

III. CONTROL FUNCTION OF THE SCADA SYSTEM

The developed intelligent system controls the following parameters:

- *Acidity (pH) of the process of fermentation* – Biological processes are heavily dependent on the pH value [6, 7]. This parameter is one of the factors that affect the production of biogas. The biogas is produced if the pH is between 6.6 and 7.6. The biogas production is highest when the pH is between 7.0 and 7.2.

- *Temperature of the process of fermentation* - Temperature inside the digester has a major effect on the biogas production process. If temperature changes, this indicates malfunctioning of temperature control system. There are different temperature ranges during which anaerobic fermentation can be carried out: psychrophilic (<30˚C), mesophilic (30–40˚C) and thermophilic (50–60˚C). However, anaerobes are most active in the mesophilic and thermophilic temperature range. An increase in temperature leads to increased bacterial activity with higher growth rates, faster metabolism and elevated nutrient demand. If temperature falls below a certain optimum bacterial metabolism and subsequent biogas production decelerates. There are several measuring points inside the digester for temperature monitoring of the whole process. The measured values are sent to a computer and they can be visualized.

- *Analysis of the biogas content* – Biogas from organic waste digesters usually contains from 60 to 70 % methane, 30 to 40 % carbon dioxide and < 1 % nitrogen. Composition of the biogas produced is measured by gas-sensors and the content of different present gases, produced by the decomposition and/or putrefaction of the substrate, is analyzed. The gas-sensors measure three principal component gases: methane, carbon dioxide and oxygen [8].

- *Control of the internal pressure* - The pressure, like the pH, influences the solubility of carbon dioxide. A decompression results in a super saturation of the liquid which as a consequence rapidly releases the carbon dioxide to the gas phase. Pressure control of the bio reactor vessel is essential and this low pressure control system (working in the range of 0 to 30 mbar) is critical for the safe operation of the plant. Interlocks are built into the systems for any over-pressure or vacuum conditions which will damage the reactor vessel.

- *Mixing condition* - The mixing plays an important role in anaerobic digestion of solid waste. Mixing provides an adequate contact between the incoming fresh substrate and the viable bacterial population and also prevents the thermal stratification and the formation of a surface crust/scum build-up in an anaerobic reactor.

- *Electrical parameters of the produced electricity*- One of the main types of biogas utilization is production of electric and heat power by means of co-generation unit. Biogas is used as a fuel. Engine moves alternator. Heat from engine cooling system and exhaust gas is recovered by heat exchangers system and is supplied to the consumer in the form of hot water (90^0C). The total efficiency of co-generator reaches 80-85%.

- *Control of the state of valves, pumps* – A biogas plant is a complex installation with close interrelationships between all parts. For this reason, centrally computerised monitoring and control is an essential part of the overall plant operation, aiming to guarantee success and avoid failures.

IV. PROCESS VISUALIZATION

The values of the technology process parameters are registered by the sensors, connected to PLC devices. The developed software visualizes processes on the operator's display in real time. On Fig. 1 is shown the SCADA configuration of the basic scheme for process control of biogas installation with 2 bioreactors: primary and secondary, temperature sensors, pH sensors, biogas pressure and chemical contents. The internal communication is realized by the Ethernet port of PLC controller and TCP/IP protocol. The data are stored in the fixed by the operator time intervals.

On Fig. 2 is shown the process of desulphurization and visualization of the values of controlled parameters.

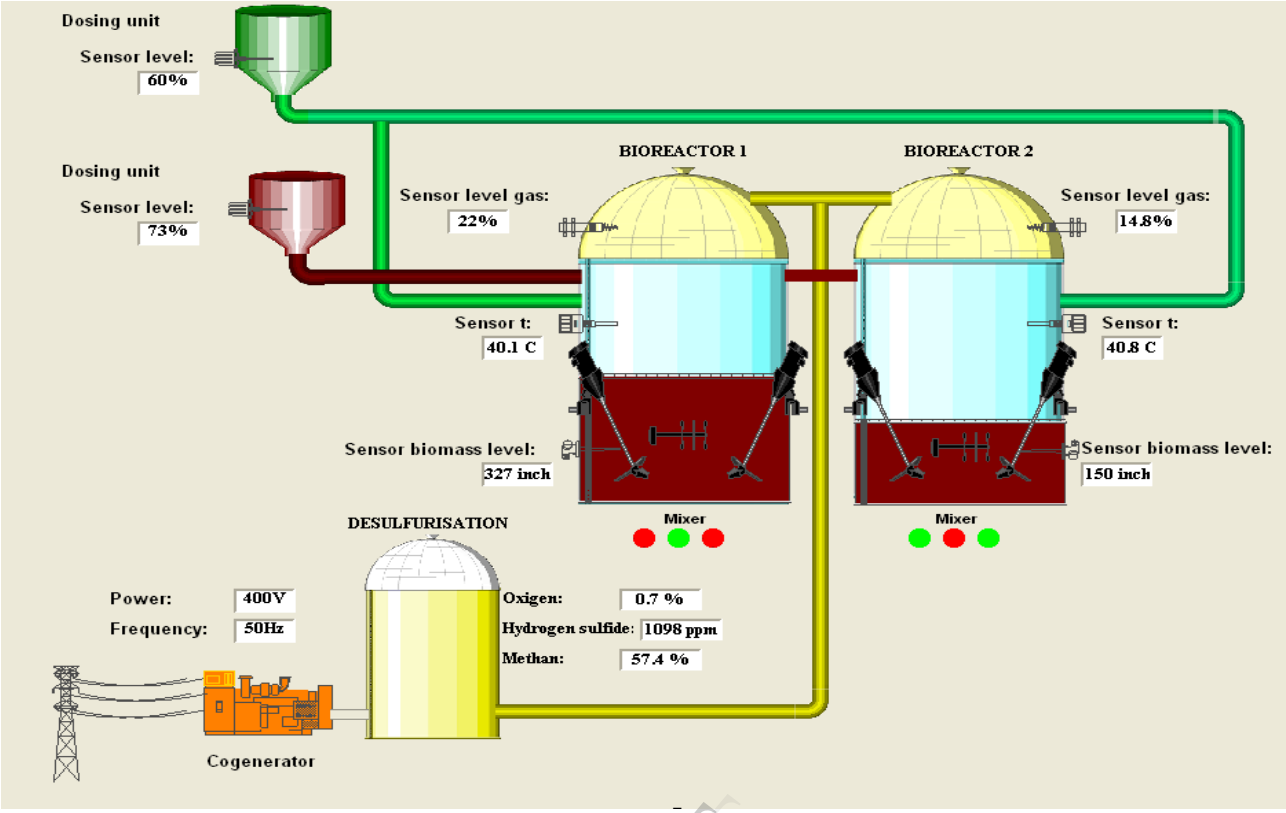

Fig. 1: The basic scheme of the process control of biogas installation

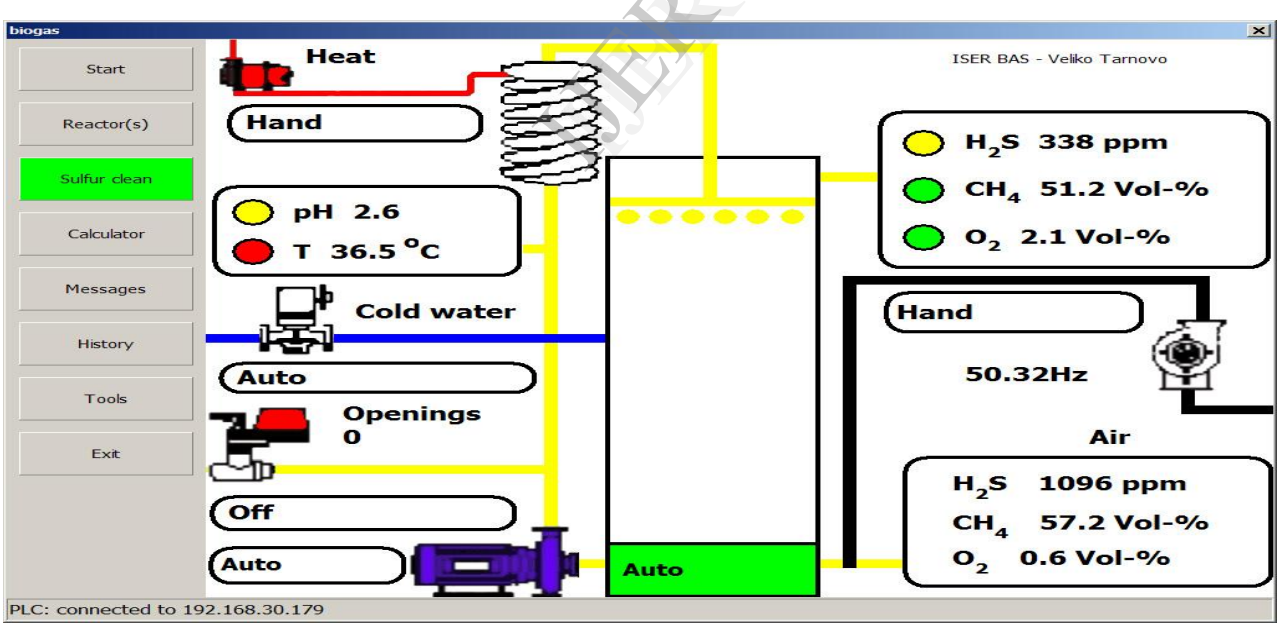

Fig. 2: Process of desulphurization and visualization the values of controlled parameters

Fig. 3: Calculation of biogas yield and electric power from different biomass source materials

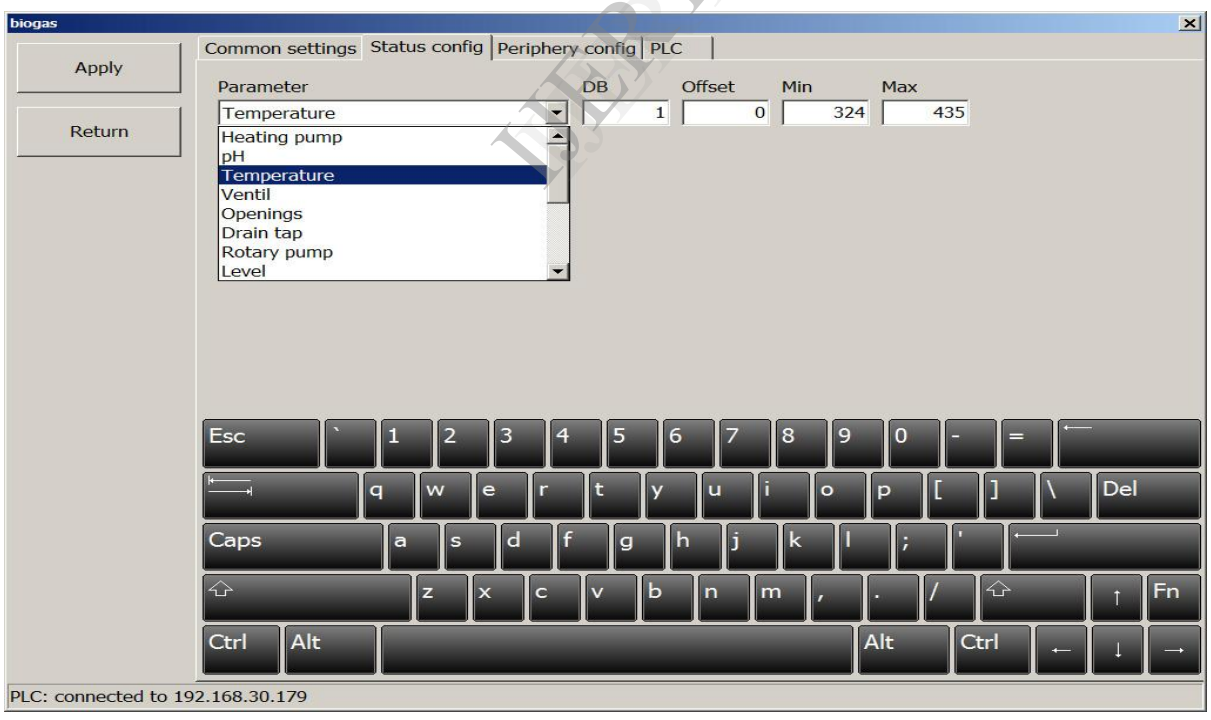

Fig. 4: Setting of monitoring system parameters

Calculation of biogas yield and electric power from different biomass source materials is shown on Fig.3. On Fig.4 is shown the process of setting the technological parameters of SCADA monitoring sub-system. The database with collected information for different parameters such as: pH, temperature, methane and generated power with values of these parameters in periods of time are shown graphically on Fig. 5, Fig. 6, Fig. 7, and Fig. 8.

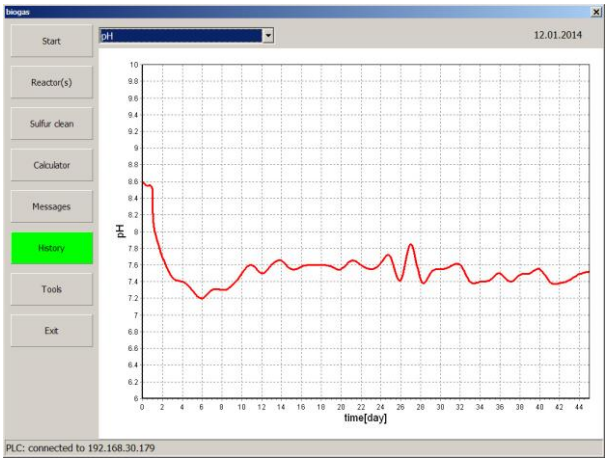

Fig. 5: Graphical results of the parameter pH in 45-days period of time

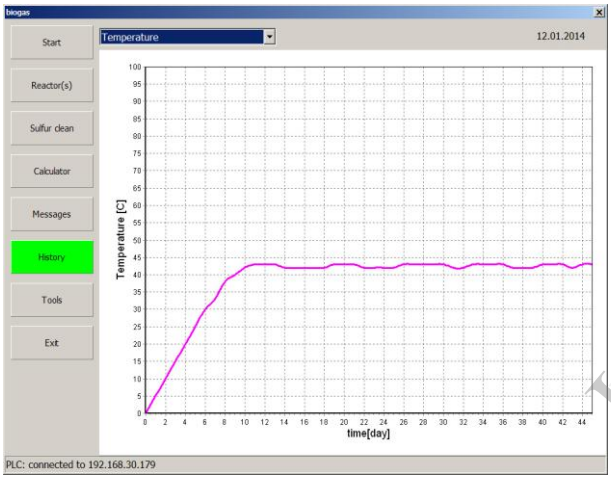

Fig. 6: Graphical results of the parameter temperature in 45-days period of time

Fig. 7: Graphical results of the parameter methane in 45-days period of time

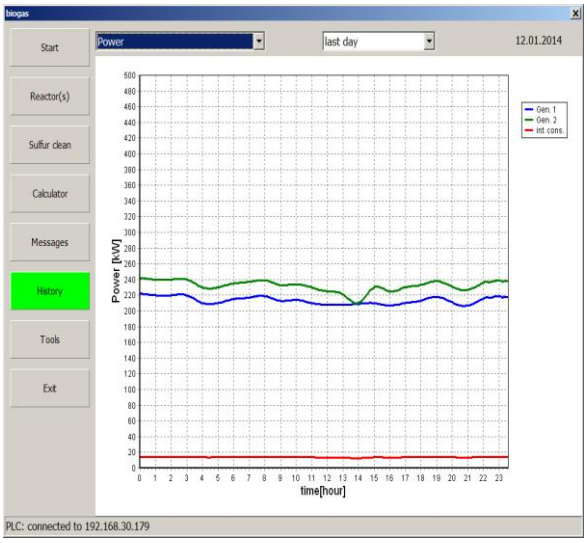

Fig. 8: Graphical results of the parameter generated power for two engines daily and own consumption

V. RESULTS

The developed intelligent system for renewable energy generation, based on the precise supervision, control and management of the installation for producing of biogas, electricity and thermal energy solve wide number of problems as follows:

- Significantly reduce the possibility of personnel error in the non interruptible process with duration around 8.000 hours per year.
- Fully automated control, messages archive and signalization.
- Registration and emergency recording of the parameters of technology process.
- Taking expert decisions for faulty of the components of the biogas installation.
- Satisfied interface of the computer system and operator – fully graphically, developed on three languages – Bulgarian, English and German for supervision, control and management of the installation.
- Printing the report in tables and graphics, as well as remote control by Internet communication.

VI. CONCLUSION

Bulgaria has a significant potential of biomass and animal waste substrates, which can be used for renewable energy generation for improvement of the local and regional energy independence [3]. In accordance to the national renewable energy source (NRES) plan 2020 about 4,5 % of the total energy consumption have to be generated by biomass (solid, biowaste, bioliquid) and biogas [4]. The modern technologies for treatment of the organic waste in combination with computerized control, based on PLC and HMI offer possibility for producing a huge volume of biogas, electricity and thermal energy with not very high amount of investment. The described project of the first biogas SCADA system in Bulgaria guarantees high reliability and productivity, low

own electricity and thermal consumption and modern way of monitoring and control of technology parameters.

ACKNOWLEDGMENT

This research was carried out as part of the project "Improving the efficiency and quality of education and research potential in the field of system-engineering and robotics" № BG051PO001-3.3.06-0002, founded by European Science Fund.

REFERENCES

[1] Benev, A. Energy from biomass. „Scientific", No. 4, 2008 г.
[2] Simeonov, I., S. Yordanov. Analysis of nonlinear dynamical models of the anaerobic degradation of organic wastes. Journal of TU of Gabrovo, Vol. 35, 2007, pp. 51-56.
[3] Mapping Renewable Energy Pathway towards 2020. European Renewable Energy Council, March, 2011, pp.31-34.
[4] Re-thinking 2050, A 100 % Renewable Energy Vision for European Union. European RenewABLE Energy Council, 2010.
[5] Dimitrova D., I. Cheriyska, K. Georgiev, D. Rutz, WIP Renawable Energies, H. Prassl, Gerhard Agrinz GmbH, K. Sioulas, CRES. Assessment of Biogas Policies in Bulgaria. ENERGOPROEKT Jsc. November 2008.
[6] Ignatova, M., V. Lyubenova. Control of biotechnological processes: new formalization of kinetics, LAP Lambert Academic Publishing GmbH & Co. KG, ISBN 978-3-8443-2623-9.
[7] Ignatova, M., V. Lyubenova, M. Angelov, G. Kostov. pH control during continuous prefermentation of yogurt starter culture by strains treptococcus thermophilus 13a and lactobacillus bulgaricus. 2-11, Comptes rendus de l' academie bulgare des sciences, 2009, 62(12), 1587-1594, ISSN 1310-1331.
[8] Wolf, C., S.McLoone, M.Bongards. Biogas Plant Control and Optimization Using Computational Intelligence Methods. Anwendungen, Vol. 12, 2009, pp. 638-650.