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THE BASE UNIT FOR BIODIESEL PRODUCTION CONTROLLING

ZÁKLADNÍ JEDNOTKA PRO OVLÁDÁNÍ VÝROBY BIONAFTY

Abstract

This work describes the control of biodiesel production from renewable and waste raw materials. Biodiesel for internal combustion engines are currently produced and used with all its advantages (reducing CO_2, produced from renewable materials) and disadvantages (higher nitrogen oxide emissions). For production of biodiesel was implemented and deployed controlling system based on programmable logic controller Saia. Programmable logic controllers are widely used and deployed from the smallest to the largest manufacturing processes in industry. The control system maintains the required parameters of a chemical reaction, in which biodiesel is created from renewable or waste raw materials.

Abstrakt

V článku je popsáno řízení výroby bionafty z obnovitelných zdrojů a z odpadních surovin. Bionafta pro spalovací motory je v současné době vyráběna a používána se všemi jejími výhodami (snižování emisí CO2, výroba z obnovitelných zdrojů) a nevýhodami (zvýšení emisí oxidů dusíku). Pro výrobu bionafty byl vyvinut a nasazen kontrolní řídicí systém založený na programovatelném automatu Saia. Programovatelné automaty jsou široce používány a nasazovány v průmyslových výrobních procesech, a to jak v těch nejmenších, tak i ve velmi komplexních zařízeních. Popisovaný řídicí systém udržuje požadované parametry chemické reakce, při které je bionafta vyráběna z obnovitelných zdrojů nebo odpadních surovin.

1 INTRODUCTION

Nowadays biodiesel is used as an alternative ecological fuel, but it has a few advantages and disadvantages. For example, advantages include production from renewable materials (oils, fats), low environmental burden and lower CO_2 emissions when is used normal biodiesel. On the other hand, production includes higher cost of some materials and there are higher nitrogen oxides emissions.

Production is providing by a transesterification of free fatty acids (see Ataya et al., 2006; Canakci & Gerpen, 2001; Van Gerpen, 2005).

Because the process was manually controlled and it was a lot of time consuming, It was designed a simple controlling system for production of biodiesel. It's based on programmable logic controller from SAIA Company.

The control system provides reactor temperature control, dosing of feedstock and other components, process visualization and easy setting and remote aces through LAN or GSM modem by text messages.

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2 FATS TRANSESTERIFICATION

Production of biodiesel runs on chemical reaction – transesterification with presence of these materials:

- Free fatty acids – used cooking oils from food-processing industry, fast foods or fats from leather remains from leather industry
- Methanol
- Catalyst, usually it is acid or alkaline, according to used raw materials, usually dissolved in methanol

Methyl esters (biodiesel) and glycerol are created by this reaction. Glycerol can be easily removed from biodiesel in centrifuge due his higher density than biodiesel.

During the development in several studies present a lot of ways of transesterification, such as parameters that can be changed:

- Temperature
- Pressure
- Catalyst
- Molar ratio methanol to oil

For example, the tests with temperature at 32°C take 4 hours, but at temperature 60°C it takes only one hour. Potassium hydroxide or sulfuric acid in the presence is used on place on catalyst, volume dependent on unsaturated free fatty acids in fats or oils.

If we want to achieve maximum yield in production and if we want reduce some next steps, we must precise control temperature, volume of materials and time.

3 THE CONTROL UNIT

The control unit is based on PLC SAIA, type PCD2.M5540. It has built - in 1 MB memory that can be extended by two flash cards. If you use extending station, you can connect 1023 inputs and outputs. This PLC has built – in web server and two RJ45 connectors for communication with touch terminal or connection to router and remote access (see Hardware PCD2.M5xxx. 26/856, 2009).

For control the stirrer speed is used 1 - phase motor driver that can communicate by a serial line with Modbus protocol or you can use analog and digital inputs. For direct control there are display and push buttons on driver body.

As the thermometers in reactor were chosen two pieces of Pt1000 thermometers with range from -25°C to +400°C. One of them measures temperature in main area, another measures temperature near the heater to avoid local overheat.

Solid state relays are used for switching pumps and heater. They have advantages in non-mechanical contacts and they switch if the alternating power supply voltage crosses through zero value, but on the other hand they need cooling for high current.

To setting and controlling the technological process is used web server and touch screen terminal. It has 10.4” screen, built – in 4 MB flash memory, which is expandable up to 1 GB. It can communicate by Ethernet or a serial line (RS232, RS485). If you use PS/2 interface, you can connect keyboard or bar-code reader.

For access control the unit is used G10/CM100 GSM modem. The setting is provided by text messages, which you can send from mobile phone or internet gate.

4 CONTROLLER STRUCTURE DESIGN

To control the reactor temperature is used two – position controller with penalization. It was also test with the PID controller set by desired model method (dynamics inverse), but time to reach the set temperature was too long.

4.1 Step response identification

To identify the step response was chosen step from 4% to 6% of heating power (from 68 watts to 102 watts). The power value was selected due to prevent overheat, because the maximal power of heater is 1700W. The static (1) and dynamics (2) characteristic were calculated from values in Table 1.

Table 1. The measured values of static characteristic.

Measurement No.	Heating power [W]	Temperature [°C]
1	68	61.4
2	85	69.0
3	102	76.0

$$y = 7.3x + 32.3 \tag{1}$$

$$G(s) = \frac{8.808}{12185.3s + 1} \tag{2}$$

4.2 Controller determination

Practically a two – position controller with penalization is an easy controller with two states and modification around the set point value, where the output level is limited. Calculation of penalty is given in the following equations (see Balátě, 2003; Vašek, 2004):

$$k_p = 1 + \left(1 - \frac{w-y}{y} \cdot \frac{1}{\frac{p_p}{2}}\right) \cdot \left(k_{p\max} - 1\right) \tag{3}$$

$$k_{p\max} = \frac{u_{\max}}{u_{str}} \tag{4}$$

$$u_{pen} = \frac{u_{\max}}{k_p} \tag{5}$$

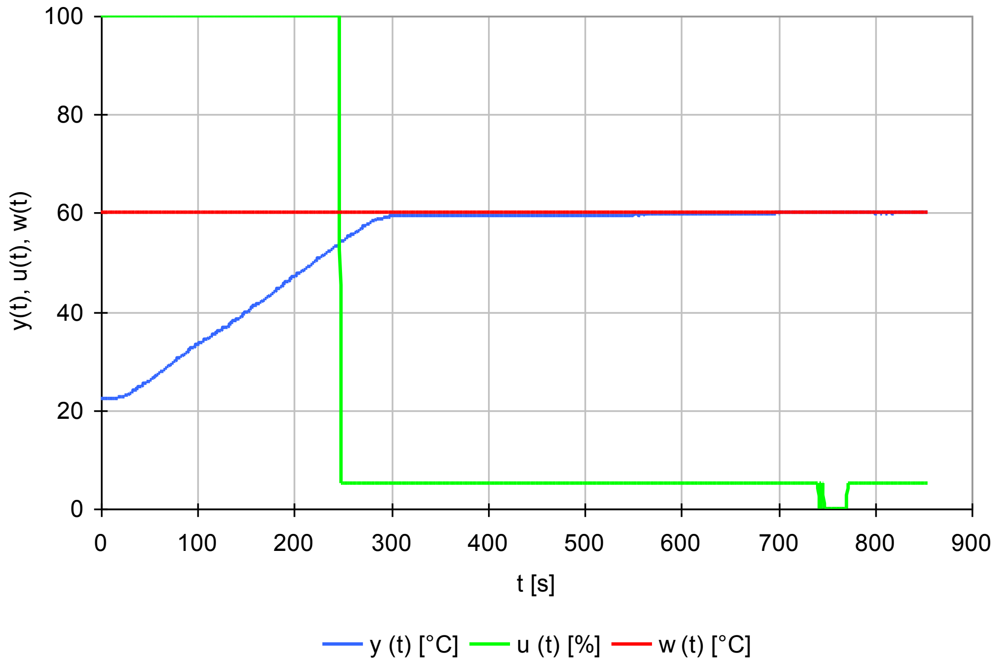

Fig. 1. Simulation of the reactor temperature control, set point at 60°C.

The best value of $k_{p\max}$ was selected from several simulations, that were performed. The value of $k_{p\max}$ can be changed in range from 0.8 to 1.2 multiple.

As show Figure 1, controlled variable reaches the set point value without overshot in time up to 4 minutes. Also you can see penalized output level when the temperature reaches 54°C. This measurement was carried out for $p_p = 20\%$.

5 VISUALIZATION OF PROCESS

Web server built – in programmable logic controller was used to for visualization of the technological process. Visualization pages made in html format can be show on the touch screen terminal or remote computer.

Devices can be controlled in two modes: manual and automatic. In manual mode user can set all output from the unit and must manually control dosing of feedstock and other materials, as you can see in Figure 2. If automatics mode is chosen, user set values of materials and it is automatically dosed into reactor. In this mode he can only stop the production of biodiesel.

In automatic mode the control unit can be controlled through GSM modem. It uses short text messages in DTMF format (see Plšek, 2011). It has next format:

*#1#500*0*1*1*1*2*1#600*0*100*1*200*3*600*4*500#*

where individual elements have the following meanings:

- # is used to separate the DTMF commands
- * is used to separate individual parameters within a DTMF command

According to the above properties we can expand the message to the following parts:

- #1 – activates DTMF server, sent SMS must always it contain
- #500 – used to set binary values, where each number is followed by the output logical value, command #500*0*1*1*0 mean that output 0 has log. 1, output 1 has log. 0, etc.
- #600 – used to set the integer parameters to output, syntax correspond to previous command, then the #600*0*100*1*200*3*600 sets output 0 to value 100, output 1 to value 200, etc.
- # - the last character terminates the DTMF command

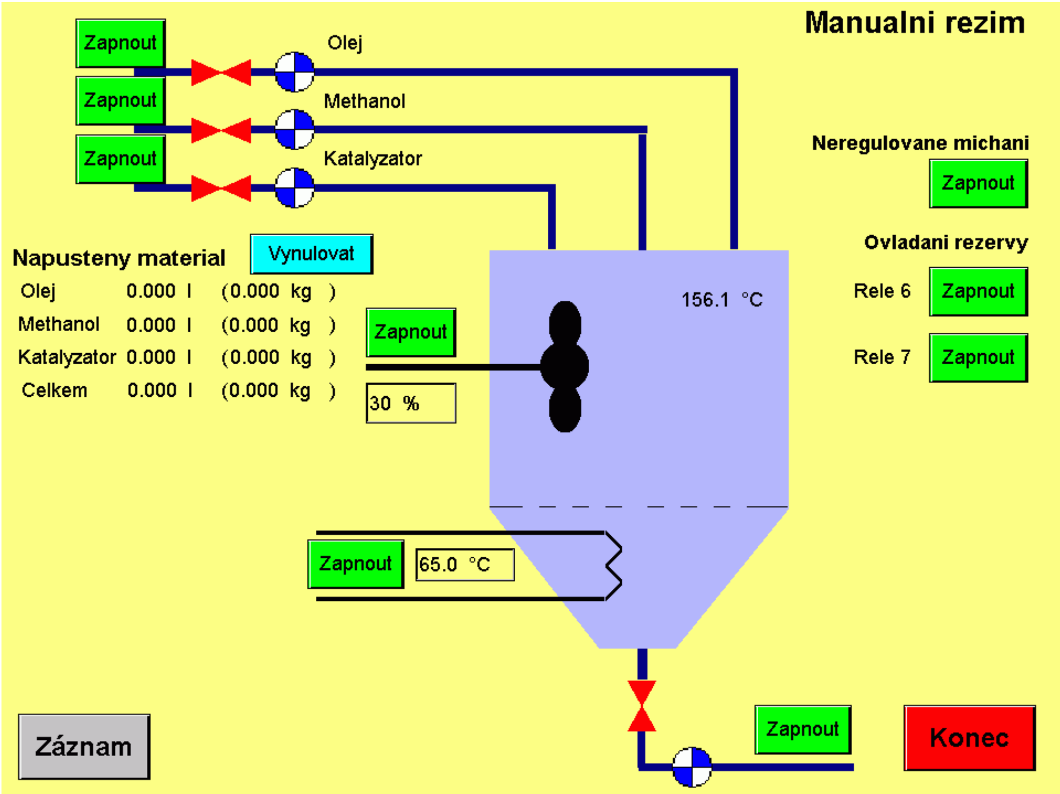

Fig. 2. Manual mode of visualization.

For easy use you can send only proper dived part of the message and set only few parameters, such as temperature or time of reaction. These messages can be saved in memory in mobile phone for faster using or you can send it by internet portal of some mobile operators.

6 CONCLUSION

The control unit has been created based on programmable logic controller. It provides temperature reactor control, dosing of feedstock and other material, control stirrer speed and monitoring and visualization of technological process with remote access through GSM modem or web browser.

The two – position controller with penalization was designed without any negative effects, such as overshot or long time regulation. The measurement with this setting was performed on real reactor and it proves the correct setting of reactor, because it was identical with simulation.

The control unit is prepared for future extension, such as control of pH in reactor or purification of biodiesel, methanol removal or preparation of used raw materials.

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