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Scientific paper

A model for multistage process unit fuzzy control

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Abstract

In this paper identification and control system to the variation of the state variables over time were investigated. Several inverse models were built. The direct introduction of fuzzy variables is the simplest way to treat uncertainty. As a case study an absorption column with three stages was used. Numerical simulation are presented to show validity of the proposed method. A fuzzy logic controller was demonstrated successfully control and to exhibit desirable robustness properties. This regulator improves quality control, determines optimum set points, updates planning models, and troubleshoots day-to-day operating problems. These capabilities allows the fuzzy controller to adapt a system which varies over time. The main contribution of this paper is fuzzy multistage control system.

Keywords: fuzzy control, uncertain parameter, absorption process, multistage control.

1. Introduction

Much of the work deals with dynamics of processes, system identification, state variable estimation, disturbance estimation, filtering, smoothing, sensor fault detection, and control of linear systems (Zadeh,1983 ;Korn,1993).

Some studies of engineering applications of fuzzy set theory have reported that, by replacing a conventional controller with nonlinear fuzzy controller, better performance and local stability can achieved. In general, fuzzy logic control systems may have better system performance. These rules and formula are hepful in eliminating the most time consuming trial-and -error method in the synthesis and design of fuzzy control systems.

A fuzzy controller uses fuzzy logic to perform real time comparisons between incoming data and historical data and can resolve fuzzy matches, error correction and image recognition.

Fuzzy system incorporates the imprecision inherent in many real systems including human reasoning by allowing linguistic variable classification such as low, high, and medium and operate by testing variables with rules which produce appropriate responses.

In this the fuzzy control system based on qualitative fuzzy variables was used for reducing the number of membership classes and input/output rules as much as possible. The developed model based on fuzzy logic for lumped parameters control, performed well for the wider operating ranges considered. The dynamic responses of the flow rate and composition control loops to a random disturbance with varying amplitude were examined.

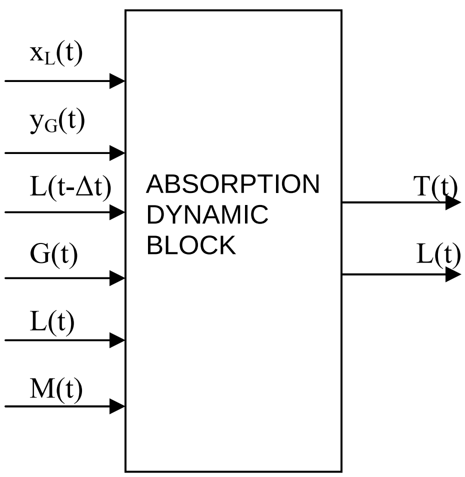

Figure 1. An absorption process unit

The qualitative model for systematic cause-event analysis was made, and variables discrete state were defined (Savković-Stevanović,2002; Bulsari et.al., 1993; Savković-Stevanović et.al.,1995).

Input variables (low, medium, high)
Output variables (low, medium, high)
Control variables (increasing, slow increasing, normal, slow decreasing , decreasing).

3. Fuzzy variables and functions

2. Stage process unit variable definition

For an absorption column, input variables might include gas flow rate and gas phase composition as disturbances, and liquid flow as manipulative variable. Output variables might include overhead gas composition, holdup, and flow rate on any or all of the stages and temperature on each stage (Figure 1).

One physical stream may be considered to contain many variables its rate, its composition, its temperature, etc..

It incorporate the imprecision inherent in many real world systems, including human reasoning, by allowing linguistic variables classification such as *big, high, slow, medium*, *near zero*, or *too fast*. Unlike binary logic, fuzzy system do not restrict a variable to be a member of a single set, but recognize that a given value may fit.

Fuzzy systems operate by testing variables with IF-THEN rules, which produce appropriate responses. Each rules then weighted by a degree of fulfillment of the rule invoked, this is a number between 0 and 1, and may be thought of as probability that a given number is considered to be included in a particular set. A wide variety of shapes is possible fulfillment functions, with triangles and trapezoids being the most popular. Fulfillment functions for this study were of the form:

$$\mu(x,m,s,p) = \exp(-(|x-m|)/s)^{p}) \quad (1)$$

where m, s, and p are user chosen parameters and x is the values to be tested. The function was chosen because of its flexibility, by changing m, s, and p whole families of different functions can be obtained. For p=2 this is an non normalized Gaussian density with mean *m*, and standard deviation *s.* A sample of the functions obtains by varying the *p*, parameter.

In ths paper the meaning of the

linguistic values is defined by left – right type membership function (Savković-Stevanović,1999; 2002; Bulsari, 1993; (Savković -Stevanović et.al.,1995).

The system operates by testing rules of different types.

IF x_i is high AND y_i is low THEN u_{ij}
is increasing etc.
The degree of fulfillment for such a rule in this study was chosen to be the minimum of the degrees of fulfillment of the antecedent clauses. The total output of the control system is calculated as weighted sum of the responses to all *n* rules outputs.

4. Inverse fuzzy models control

With the inverse dynamics modeling the control variables, in order to make the plant output, follow the desired set-point. These inputs can be randomly generated, but they must preferable cover all the input domain. The plant input and output are considered during the simulation.

Liquid flow rate L is a manipulated variable u(k), composition of the gas phase at the top y_T is controlled variable y(k) and s(k+1) is desired point value.

The inputs in a fuzzy control system are shown in Figure 2.

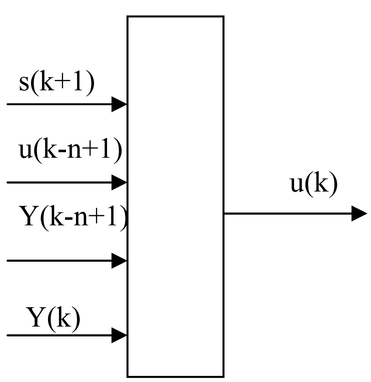

Figure 2. Inverse control model

The inverse dynamics of the absorber with packing is modeled by applied the input from the initial state of the stage and the final state of the stage.

u(k) = f{Y(k), Y(k-n+1),s(k+1), u(k-n+1) } (2)

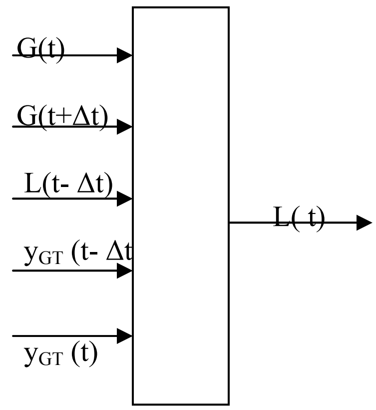

Figure3. A gas flow rate control system model

Dynamic control function for gas flow rate is:

L(t)=f(G(t), G(t+ Δt), y_{GT} (t- Δt), y_{GT} (t), L(t- Δt)) (3)

Corresponding fuzzy rules can be generating as shown in section 6.

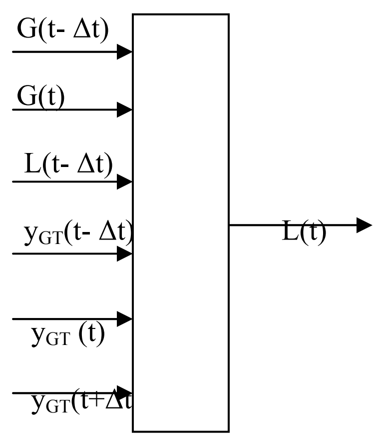

Figure 4. Outlet gas composition control system model

Dynamic control for outlet gas composition is:

$L(t)= f(G(t),G(t-\Delta t),y_{GT} (t-\Delta t), y_{GT}(t), y_{GT} (t+\Delta t), L(t-\Delta t))$ (4)

Corresponding fuzzy rules is shown in section 5.

Many other systems were designed for control. One of them is shown in Figure 5

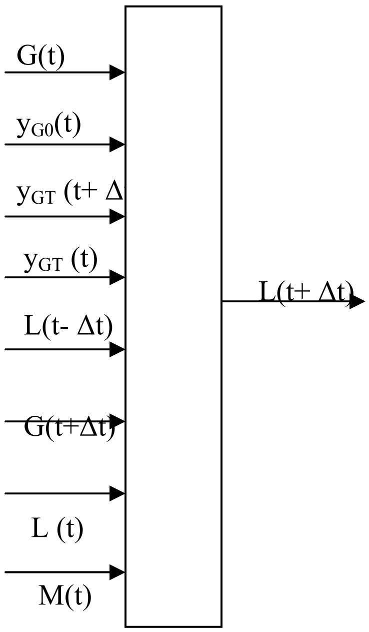

Figure 5. An inverse gas control model incorporating inlet gas phase composition changes

Control function for outlet gas composition control is:

$L(t+\Delta t)=f(G(t), G(t+\Delta t), y_{G0}(t), y_{GT} (t+\Delta t), y_{GT} (t), y_{G0}(t), L(t- \Delta t), L(t),M(t))$ (5)

5. Fuzzy rules sets for absorbtion plant control

A fuzzy control system was generating using a many fuzzy rules. Some of them follow:

Rule set number 1:

IF L(t) is decreasing THEN G(t+Δt) is decreasing following G(t).
IF L(t) is increasing THEN G(t+Δt) is increasing following G(t).

Rule set number 2:

IF L(t) is high AND G(t) is medium THEN $y_{GT}(t+\Delta t)$ is decreasing following $y_{GT}(t)$.
IF L(t) is low AND G(t) high THEN $y_{GT}(t+\Delta t)$ is increasing following $y_{GT}(t)$.

Rule set number 3:

.
IF $y_{G0}(t)$ is high AND G(t) is high THEN L(t+Δt) is increasing.
IF $y_{G0}(t)$ is low AND G(t) is low THEN L(t) is decreasing.

6. A case study

An absorption column for ammonia absorption by water (Savković-Stevanović et.a.,2005a) was used as shown in Fig.6. The main state variables characterizing of the process are liquid flow rate L, ammonia composition of the gas phase y_{G0} in inlet, ammonia composition of the gas phase y_{GT} at the outlet of the column and temperature of the liquid phase T_L.

The steady state parameters for examined process are given in Table 1 (Savković-Stevanović et.a.,2005b).

Table1. The steady state parameters

Gas flow rate G, kg/h	45.664
Inlet gas composition y_{G0}, kg/kg	0.3000
Outlet gas composition y_{GT}, kg/kg	0.0025
Liquid flow rate L, kg/h	98613.00
Liquid phase composition w,	0.025

kg/kg	
Liquid temperature T_L in inlet , ˚C	45.0
Hold up,kg	670.0
Pressure at the top, bar	1.05

A dynamic model for the absorption column control can be obtained using of the first principle modeling approach.

Total material balance,

$$L - G = \frac{dM_{tot}}{dt} \qquad (6)$$

for stage j,

$$L_{j+1} + G_{j-1} - L_j - G_j = \frac{dm_{tot,j}}{dt} \qquad (7)$$

Total energy balance,

$$L_{j+1}h_{j+1} + G_{j-1}H_{j-1} - L_j h_j - G_j H_j = \frac{dU_{tot,j}}{dt} \qquad (8)$$

Component material balance,

$$L_{j+1}w_{i,j+1} + G_{j-1}y_{Gi,j-1} - L_j w_{i,j} - G_j y_{Gi,j} = \frac{dm_{j,i}}{dt} \qquad (9)$$

where L is liquid flow rate, G is gas flow rate, M is total holdup and m is holdup on the stage, H-enthalpy of the gas phase, h is enthalpy of the liquid phase, U is energy, *w* is liquid phase composition, *y* is the gas phase composition.

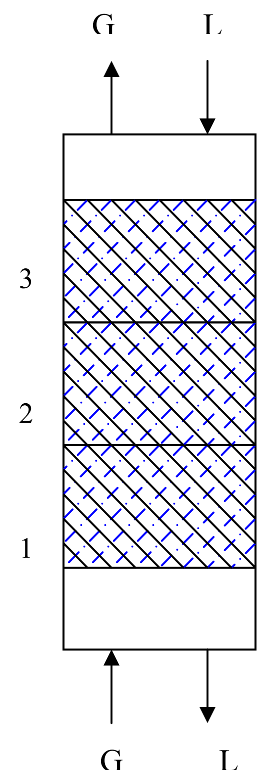

Figure 6. The absorption column scheme

7. Results and discussion

A random disturbance were used for control response. The investigation is carried out during a time period from 0 to 2400s. The process inputs and outputs are considered during the simulation. The sampling interval was 10s.

The obtained control results are shown in Figure 9- Figure 11.

In Figure 7 disturbance to the liquid flow rate is shown.

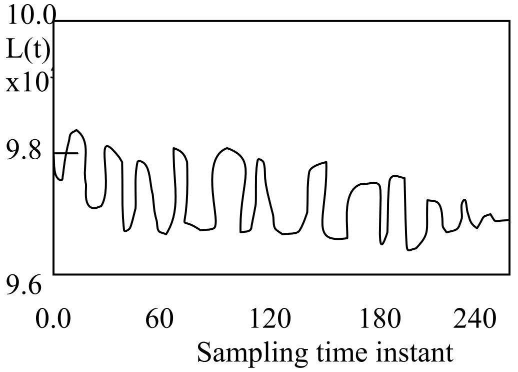

Figure 7. Disturbance in the liquid flow rate

In Figure 8. disturbance in inlet gas composition has shown.

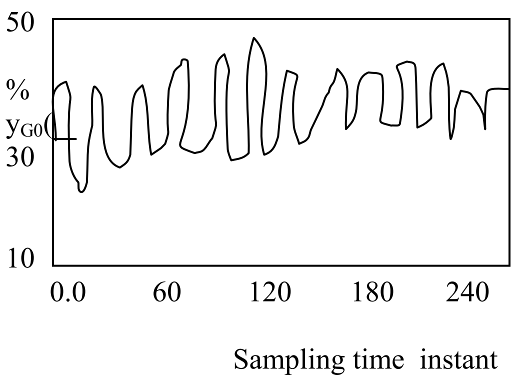

Figure 8. Disturbance in the inlet gas composition

Dynamic response of the outlet gas composition to disturbance in the liquid flow rate is shown in Figure 9. Dynamic response of the liquid flow to disturbance in inlet gas composition is shown in Figure 10. The response of the liquid composition on the 2nd stage to the disturbance in the inlet gas composition is shown in Figure 11.

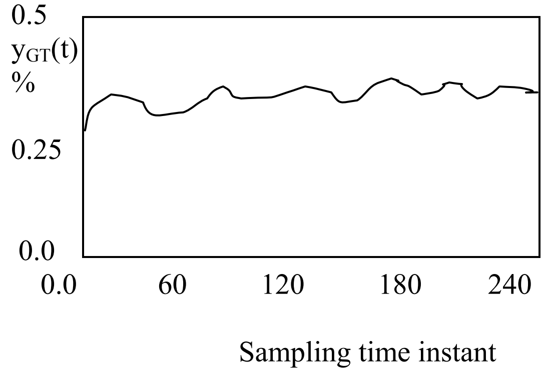

Figure 9. Dynamic response of the outlet gas composition to disturbance in the liquid flow rate

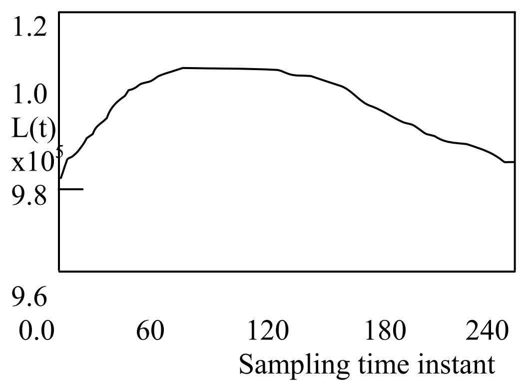

Figure 10. Dynamic response of the liquid flow to the disturbance in the inlet gas compositio

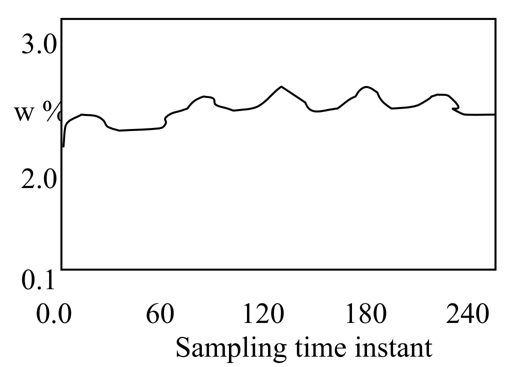

Figure 11. Dynamic response of the liquid composition on the 2nd stage to the disturbance in inlet gas composition

8. Conclusion

This paper illustrates fuzzy logic control application to a multistage absorption process. Inverse models of the fuzzy controllers are derived. The developed model based on fuzzy logic for lumped parameters control, is performed well for the wider operating ranges examined.

The fuzzy logic control system developed based on input/output data. The dynamic responses of the flow rate and composition control loops to a random disturbance with varying amplitude were examined.

This paper shows ability to apply fuzzy control to the state variables in absorption column. The non stationary characteristics of the process is handled by feeding, information of the state variables, and not only the control error, to the fuzzy controller.

The obtained results in this paper can be applied in the other domain.

Acknowledgment. The authors wish to express their gratitude to the Fund of Serbia for financial support.

Notation

G-gas phase flow rate, kg/h
H-gas phase enthalpy, J/kg
h- liquid phase enthalpy, J/kg
L-liquid flow rate, kg/h
M-total holdup, kg
m- holdup on stage, kg
s-set point
T- temperature, ^{0}C
U-energy, J
u-manipulated variable
w-weight fraction, kg/kg
y_G-gas phase composition, weight fraction, kg/kg
Y-control variable

Index

G-gas
L-liquid
j – any stage
i- any component
0-inlet
T-top

Greek symbol

Δt-sampling interval

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IZVOD

MODEL FAZI REGULACIJE VIŠESTUPNJEVITE PROCESNE JEDINICE

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U ovom radu je ispitivana identifikacija i re gulacija sistema na variranje stanja promenljivih u toku vremena. Izgrađeno je nekoliko inverznih modela. Direktno uvođenje fazi promenljivih je najjednostavniji način tretiranja neizvesnosti. Kao slučaj za ispitivanje korišćena je apsorpciona kolona sa tri poda.Data je numerička simulacija da pokaže validnost predložene metode. Fazi logički regulator je demonstrirao uspešnu regulaciju i pokazao željene robustne osobine. Ovaj regulator poboljšava kvalitet regulacije, određuje optimalni početni set, ažurira planirane modele i otklanja operativne probleme iz dana u dan. Ove sposobnosti dozvoljavaju fazi regulatoru da adaptira sistem koji se menja. u toku vremena. Glavni doprinos ovog rada je fazi sistem stupnjevite regulacije.

Ključne reči: Fazi regulacija, neizvestan parameter, apsorpcioni process, višestupnjevita regulacija.