Study on PID Control System Based on Genetic Algorithms

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***Abstract*-As for the characteristics of hysteretic, nonlinear and time-varying after aeration process, the control of the dissolved oxygen concentration DO is as the mathematical model object, with the use of fuzzy PDI control strategy through the comparison among the MATLAB simulation, PDI control and the applicable results for the conventional fuzzy control strategy. Because the fuzzy control parameters of the fixed PDI can't be guaranteed various conditions on the control effect of DO, thus, genetic algorithms can't be automatically optimized several key parameters to design the fuzzy PDI control: the membership function, rule table of fuzzy control and the scale factor, then MATLAB simulation is carried out, with the comparison among the PDI control based on genetic algorithms, conventional fuzzy control strategy and the simulation results.**

Keywords*: *Fuzzy Control, Genetic Algorithm, PID Control, Sewage Treatment

I. INTRODUCTION

Fuzzy control in water treatment has been successfully applied, especially used in dealing with the intermittent discharge, water quality and the various quantity sequencing batch(SBR method), which is complex and dynamic engineering system. The main drawback is the complex operation and management; only achieve the SBR method automatic control can play its advantages [1]. Currently, the research is to predict the effluent suspended solids and control of activated sludge method of dynamic fuzzy control [2]. Fuzzy control is applicable to the high-oxygen activated sludge method, which can prevent the energy waste and avoid the lack of dissolved oxygen [3].The dissolved oxygen is the SBR method object of fuzzy control, which can accurately reflect the changes in effluent quality and reasonably control aeration [4]. Biological electrode is applicable to fuzzy control, which can help to avoid excessive dosing of organic matter and save the operating costs [5]. PH value is proposed on intelligent fuzzy control, which makes the system has strong robustness and adaptability. As for the ditch treatment for biological oxidation system has the system control problem with large inertia, long delay and some uncertainty, one state key laboratory environment for simulation and pollution control has introduced the migration bias based on the simple fuzzy controller, and used S-curve quantify and dynamic regulation bias and stability control migration to gradually approach the precise control of output targets and achieve the high-precision control for fuzzy control. The coagulant delivery control system combined with fuzzy control and expert control has been designed on a water plant, which can improve the water quality, save the consumption of raw materials, reduce the cost of water and the labor intensity of labor operation [6]. Fuzzy control technology has been applied to the wastewater treatment for 3-ditch-type oxidation ditch in one sewage treatment plant, with the well effect [7].

In this paper, as for the actual environment in sewage treatment plant, a variety of forms of network has been analyzed, the distributed monitoring system instead of the conventional instrument based on the Ethernet network and

CC Link field bus has been proposed, to achieve the line testing for the equipment operating parameters in sewage treatment process. The running and process of equipment has been recorded and analyzed the various trends in the parameters, which can timely release and predict the operation, in the implementation of diagnostics and alarms by the remote monitoring and control, with the intuitive guidance, which can facilitate the whole process of the production for the operator to manage the productive technology.

II. THE BASIS FOR PID CONTROL THEORY

A. The Traditional Closed-loop Control System

The traditional closed-loop control system is shown in Figure 1, which is normally consisted of controller, actuator, manipulation and feedback. The data control system is just that the computer is replaced the analog control digital control system in Figure 1, and two basic units like AD and DA, are added in the return circuit.

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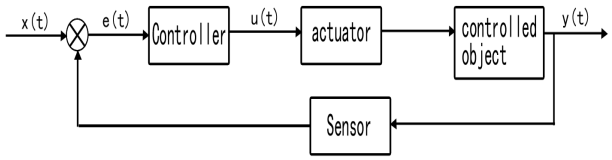

Figure 1. the basic structure of traditional closed-loop control system

B. PIO Control Principle

In traditional control theory, the most basic but also the most common adjustment rule is PDI regulation, the characteristic of this control algorithm is inclusive non-linear factor. PDI controller is multiple controllers that are proportional, integral and differential, which can be expressed as:

$$u(t) = K_r \left[e(t) + \frac{1}{T_i} \int_i^e e(t)\,dt + T_d \frac{de(t)}{dt} \right] \quad (1)$$

Of which: u (t) output for controller e (t) input for controller, which is the difference for set value and controlled object, with the name error signal Kp, Ti, Td are respectively the scale factor for controller, integral time and derivative time.

III. THE DESIGN ON OPTIMAL FUZZY CONTROLLER FOR GENETIC ALGORITHM

A. Genetic Algorithm Optimization of the PID Control Algorithm

The key to adjust PID controller performance is the parameter selection for KP, K and KD to optimize with genetic algorithm for KP, Ki, and KD, which can make PID tuning parameters change with the object, so that PID control can achieve the best results under any circumstances. When PID control parameters are in the optimization, binary code, real number encoding or real-coded encoding can be adopted.

The control system overshoot is used for the evaluation of performance quality in various control algorithms. $\sigma\%$ and the settling time Ts can be evaluated: in order to obtain the satisfactory dynamic characteristics during the transition process, the use of absolute time integral performance parameters are as the minimum objective function; to prevent the excessive control energy in the objective function, quadratic component is added on the control input on target function. The following formula is selected as the best indicator of the parameters:

$$J = \int^{\infty} \left(w_1 \left| e(t) \right| + w_2 u^2(t) \right) dt + w_3 t_u \quad (2)$$

Where, e (t) is the system error, u (t) is the output of the controller, tu is the rise time, wl, w2, w3 are values. To avoid overshoot, penalty function is used, that is, once overshoot, exceed amount is transferred as the most excellent indicator, and then the best indicators are the following:

$$if \quad e(t) < 0, \qquad J = \int^{\infty} \left(w_1 \left| e(t) \right| + w_2 u^2(t) + w_4 \left| e(t) \right| \right) dt + w_3 t_u \quad (3)$$

Where, w4 is the right value, w4>> wl.

B. The Optimization of Fuzzy Control Algorithm in Genetic Algorithm

a) The optimization for the degree of membership in function

The determination of degree of membership function is one of the key steps on design the fuzzy controller. It is the basis to solve practical problems on using the fuzzy set theory. For the triangular membership function, we can see that its shape is determined by three parameters: the distance between a and b from the apical abscissa x and x, thus, the total parameters is 3 times as the sum of fuzzy subset. The number of optimized parameters can be determined according to its coding accuracy, and all the parameters of the encoding string together to form a chromosome. Encoding can be used after to determination its genetic algorithm optimization

b) The optimization of the fuzzy control rules

The choice of fuzzy control rules is directly related to the goodness or badness of fuzzy controller performance. When the control rules of fuzzy controller is determined, all the control rules are unfolded as the one-dimensional according to certain order and encoded as an individual. Random selection is for certain number of individuals as the initial population, the genetic manipulation for the individuals can achieve the optimization of fuzzy control rules.

c) The optimization for the quantitative factors and the scale factor

The results show that [8]: the relative relationships among the quantify factor Ku of fuzzy controller, the size of scale factors like Ke and Kec and the relative factors of the same quantization, which greatly affect the performance of static and dynamic control in the fuzzy controller and fundamentally change the output characteristics. As the choice of scale factor and the quantization factor is an iterative process of trial, the global optimum is found by the optimization algorithm. The optimization process for quantization scale factor and factor are similar to the optimization process for PDI control parameter

IV. THE SIMULATION RESEARCH FOR THE CONCENTRATION CONTROL SYSTEM ON DISSOLVED OXYGEN IN GENETIC ALGORITHM OPTIMIZATION

A. PID Control System Simulation based on Dissolved Oxygen Concentration for Genetic Algorithm

As the binary encoding quantization error will inevitably involve the trade-offs and encoding length, while the space discrimination of continuous optimization objective function will lead to distortion, so the dissolved oxygen concentration of the PID parameters is used the real-coded encoding method. According to Ziegler—Nihcols made the PID control parameters derived from the formula is the following: Kp = 0.00197, Ki = 0.0000246 and Kd = 0.0394, to determine the range of optimization of Kp, Ki and Kd: [0,0.005], [0,0.0001] and [0,0.05]. The group size is = 30, crossover probability is 0.9 and mutation probability is 0.1.

After 100 generations of evolution, the optimal parameters obtain are the following: KP = 0.00246, Ki = 0.0000 and KD = 0.0285, the corresponding step is the response curve.

B. Fuzzy Control System Simulation of Dissolved Oxygen Concentration based on Genetic Algorithm

In this paper, the optimal fuzzy controller of dissolved oxygen is designed with the genetic algorithm through overall concentration, the membership degree of function, fuzzy control rules, optimization of scale factor and quantitative factors have been solved. The new encoding has been presented, with the combination of all the items to be optimized with the unified coding and the corresponding improvement of the genetic operators.

As there are many parameters to be optimized in this paper, with higher requirements of precision, therefore, code will become longer with binary coding, which has affected the convergence speed of algorithm and the increased the burden of CPU. The code length is relative short as the terms of real number encoding, which makes the mutual mapping for the code values and the physical meaning of each control rule mapping. The accuracy is also easy to control with the real number encoded mode.

a) The code of membership function

According to the fuzzy controller of dissolved oxygen concentration designed on Chapter III, there are 7 fuzzy sets {PB, PM, PS, ZO, NS, NM, NB} E, EC and U. Isosceles triangle membership function is selected the degree of membership function of fuzzy set, so there are14x3 optimized parameters of membership degree function.

Because the corresponding degree of membership function vertices of NB, PB, and 20 are fixed, and the membership function curve is symmetric, so the parameters to be optimized can be reduced to 18. Encoded string is:

{x11，x12，x21，x22，x31，x32，r10，r11，r12，r13，r20，r21，r22，r23，r30，r31，r32，r33}

Xli and r1j mean the optimization parameters of error E, and x2i and r2i mean the r2i optimization parameters for error change rate; x3i and r3i U mean the U optimization parameter of output control.

In order to improve the search efficiency of genetic algorithm and ensure the genetic algorithm optimization within the range of effectiveness individuals, the following constraints are given:

1. the relationship for the abscissa of all the triangle peaks: X (NB) <x (NM) <X (NS) <0

2.X(NB)=-X(PB)，X(NM)=-X(PM)，X(NS)=-X(PS)，L(NB)=L(PB)，L(NM)=L(PM)，L(NS)=L(PS);

3. L (ZO) <|X (NS)|+L (NM);

L (NS) <MIN (|X (NM)-X (NS)|+L (NM), |X (NS)|+L (ZO));

L (NM) <MIN (|X (NB)-X (NM)|, |X (NM-X (NS))|+L (NS));

L (NB) <|X (NB)-X (NM)|+L (NM);

4. L (NS) +L (ZO)>X (NS);

L (NS) +L (NM)>|X (NM)-X (NS)|;

L(NB)+L(NM)> |X(NM)-X(NB)|。

b) The selection of the fitness function

The performance for evaluation the fuzzy control algorithm can also be used control system overshoot. $\sigma\%$ and the settling time can be used. Therefore, the same original fitness function can be applied to optimization process for the genetic algorithm in fuzzy control.

c) Genetic manipulation

For the encoded mode of the optimization object on fuzzy control system, with the consideration of the existence of continuous parameters (membership function parameters and scale factor, quantization factor) and discrete parameters (fuzzy control rules) at the same time, the improvements for the conventional genetic algorithm has been made to enhance the algorithm's search performance.

d) The selection for the operator

Taking into account the standard genetic algorithm selection operator is conducting before crossover and mutation, so the results do not guarantee the offspring individual can be better than the individual parent. Children completely replace parent, which may lead to losing of good genes. Therefore, operator will be used after the crossover operator and mutation instead of directly replacing parent, but do it together with parent to choose. In order to prevent premature, league selection method is used, and the size is taken 2, that are two individuals are arbitrary selection, and the low fitness will be selected into the next generation. Combined with the best methods of protection individuals that is lowest degree for each generation don't be adapted cross-matched but directly copied to the next generation.

e) Crossover operator

The crossover operator for real-coded is the same as binary encoding , which can be used with the same point or points that can be used to the crossed way, but the role of the object for the crossover is a column or row, which can be conducted by subsection. The parameters of different attributes to be optimized can be separated crossover. The crossover operator has the value characteristics of crossover operator that is to take a linear combination of two vectors.

d) The mutation operator

In the decimal encoding, mutation operator is the key operator for algorithm to achieve the rapid and global search, of which effect is far greater than binary code.

The variation algorithm is conducted according to the following algorithm: S = (v1, v2, vn) is parent, each of its components is heteromorphosis with the same probability, and results of the mutation of are S'= (VL, v2, vk', vk +1, vn). If the domain of vk' is [ak, bk], then vk' value can be determined.

V. CONCLUSION

The contents of this paper is related to biochemistry, physics, automation, machinery, electronics technology, computer technology, communications, networking, instrumentation and water treatment etc, which is the complex and comprehensive research. With the analysis of the basic principles of treatment, the advanced intelligent control strategy has been used in the sewage treatment system, which has played an active role on the improvement of production efficiency of sewage treatment plant and

reduction of energy consumption.

REFERENCES

[1] Kaijun Wang, Limin Jia. The new technology development and application for wastewater treatment in the city. Chemical industry press. 2001.198 ~ 209

[2] TsaiY.P. et al. Effluent Suspended Solid Control of Activated Sludge Process by Fuzzy Control Approach. Wat Environ Res. 8.6 1996.1045~1053

[3] Mark T Yin，Fuzzy Logic Process Control OF HPO-AS，Journal of Environmental Engineering，1996

[4] Peng Yongzhen, Wang Shuying, Zhou Li etc. The control study on online fuzzy control in biological electrode denitrification (ii). China's Water and Wastewater Engineering. 1999.4

[5] Wu Jianhui, Zhang Jing, Hou Qingping. The application of wastewater treatment in human-simulated intelligent fuzzy control. Computers and information technology. 2000.1.8 ~ 10

[6] XiaoJun. The application on fuzzy control on water plant. Automation and instrumentation. 1999.5.25 ~ 26

[7] Goldberg. D E. Genetic Algorithms in Search, Optimization and Machine Learning MA. Addison-Wesley Publishing Company1989

[8] Tan Guanzheng, Hu shengyuan. The online self-adjusting fuzzy controller of parameter based on the genetic algorithm. Academic journal of Zhongnan poly-technical university (natural science edition).2003, 34 (6): 285 ~ 289

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