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SISO P-ILC Algorithm for Output Data Dropouts and Its Application in Wastewater Biological Treatment Plant

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Abstract

In order to improve the efficiency of sewage treatment, we construct P-ILC algorithm for output data dropouts. The P-ILC algorithm is used in the aeration tank of oxygen input link, and according to the actual situation, considering the data generating omissions, adjusting the algorithm can completely control the aeration tank of oxygen. After 15 iterations, we can completely control the oxygen in the aeration tank volume. We know more important is this algorithm may at any time according to need of aeration tank of oxygen supplement, when the lack of oxygen, can open the oxygen filling pump, when sufficient oxygen, close the oxygen filling pump, to achieve energy saving goals, ultimately makes the economic benefits to achieve the highest.

Keywords*: iterative learning control, output data, data dropouts, wastewater treatment process, simulation*

1. Introduction

Water refers to the overall amount of water on earth. Including the human control and surface water and groundwater directly for irrigation, power generation, water supply, shipping, aquaculture and other purposes, as well as the rivers, lakes, wells, springs, tidal, harbor and water area. Water resources are important natural resources indispensable for the development of the national economy. With the development of the world economy, population growth, increasing and expanding around the city, with water rising. The United Nations estimates, in 1900, the global water consumption is only 4×10^{11} cubic meters / year, 1980 is 3×10^{12} cubic meters / year, 1985 is 3.9×10^{12} cubic meters / year. It is expected that by 2000, demand will increase to 6×10^{12} cubic meters / year. In Asia with the most water, up to 3.2×10^{12} cubic meters / year, followed by North America, Europe, South America etc. By 2000, China national water demand is expected to be 6.814×10^{12} cubic meters. Most of them for the Yangtze River Basin, 2.166×10^{12} cubic meters, followed by the Yellow River and the Pearl River basin. With the development of production, the contradiction between supply and demand of regional and national water resource is increasingly prominent. Along with sewage reuse problem has become a topic of concern. According to the classification of the source of wastewater, wastewater treatment is generally divided into the production of sewage treatment and sewage treatment. According to the classification of the source of wastewater, wastewater treatment is generally divided into the production of sewage treatment and sewage treatment. Production sewage including: industrial wastewater, agricultural wastewater and medical sewage. Sewage is sewage generated daily life, is a complicated mixture, refers to various forms of inorganic and organic include: the size of solid particles of floating and suspended; gel and gel diffusion in pure solution. According to the quality of water pollution, water pollution has two kinds: one kind is the natural pollution; the other is man-made pollution. The harm of water is man-made pollution. Water pollution according to the different pollution of impurities is: chemical pollution, physical pollution and biological pollution three categories. The main pollutants are: the industrial wastewater discharge of untreated; the discharge of untreated sewage; the extensive use of fertilizers, pesticides, herbicides farmland sewage; the stacked in the industrial waste and

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domestic waste; the soil and water loss; the mine wastewater. Many methods of wastewater treatment, generally can be divided into physical method, chemical method and biological method.. This paper focuses on city life sewage biological treatment in two stage aeration tank dissolved oxygen (DO) concentration. For the DO process control, including PID control, adaptive control, nonlinear control, has a large number of papers published. In recent years, the research of fuzzy control and neural network control in intelligent control to stabilize the DO value, provides some deal with the nonlinear and uncertain means and methods of process. Ferrer, Rodrigo et al. [1] describes the control process of the mould for biological wastewater treatment process modeling, control and optimization of fuzzy controller in 1998, control rule is obtained by summing up the operator's experience. Yu and Liaw proposed [2] real-time control method for in 1998. Bongards M et al. [3] developed a combination of fuzzy control and neural network control scheme in 2001. Pu ñ al A, Rocca E, 2002 [4] and 2004 [63] proposed the expert control system applied in sewage treatment in the case. Bongards M and Ebel A [5], described in 2004 for the DO control based on another kind of neural network predictive control scheme. Piotrowski et al. [6] is the method using hierarchical model to implement effective control of DO, and design a hierarchical controller to guarantee the DO concentration accurately track a desired trajectory, ensure that the nitrogen and phosphorus in sewage can be effectively removed. Holenda et al. [7] using model predictive control (MPC) method is used to control the sewage treatment process of aerobic pool of DO concentration, and achieved good results. This paper will consider data loss situation, the P type iterative learning control algorithm is used to control the DO concentration. When the lack of oxygen, can open the oxygen filling pump, when sufficient oxygen, close the oxygen filling pump, to achieve energy saving goals. Figure 1 is a simplified biological sewage treatment flow chart.

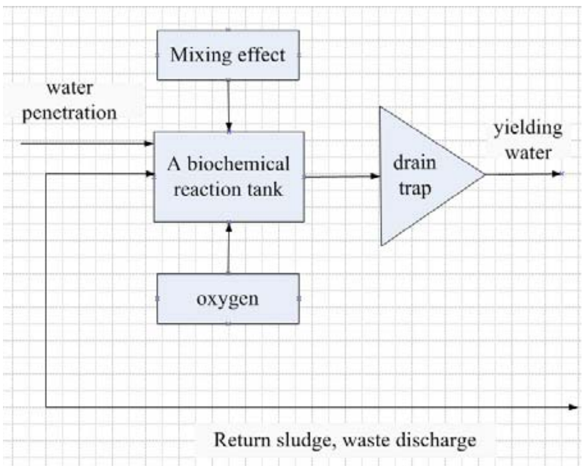

Figure 1. A Simplified Biological Sewage Treatment

2. Research Method

2.1. Calculation Methods of Dissolved Oxygen Aeration Tank

The time rate of change of concentration:

$$V\frac{dS_o}{dt} = Q_{in}S_{o,in} - Q_{out}S_o + VK_L a(S_{o,sat} - S_o) \quad (1)$$

Where V is the volume of aeration tank, It is measured in m^3, Q_{in} is the amount of water, Q_{out} is a water flow, It is measured in m^3/h, S_o is the concentration of dissolved oxygen, It is measured in mg/L, $S_{o,in}$ is the concentration of dissolved oxygen in water,It is measured in mg/L, $S_{o,sat}$ is the saturation of dissolved oxygen concentration, It is measured in mg/L,

K_L is the absorption coefficient, a is the ratio of area and volume(On an open no aeration pool, its area refers to the area of contact of air and water, volume refers to the volume of the pool. In an aerated pond, the contact area with air and water of bubble size, bubble size is a function of aeration equipment and air flow), $K_L a$ for the dissolved oxygen mass transfer coefficient, It is measured in $1/h$.

2.2. SISO Problem with P-ILC Algorithm for Output Data Dropouts

For a multiple input multiple output nonlinear system:

$$\begin{cases} x_k(t+1) = f(x_k(t)) + b(x_k(t))u_k(t) \\ y_k(t) = c(x_k(t)) + d(x_k(t))u_k(t) \end{cases} \tag{4}$$

Where k is the number of iterations,

$x_k(t)$, $u_k(t)$, $y_k(t)$ As the system state variables, system input variables and the output variable of the system [8].

Hypothesis 2.2.1: The state variable $x_k(t)$ satisfies Lipschitz condition, the presence of $a(x)$, $b(x)$, $c(x)$, $d(x)$ such that for any time $t \in [0, N]$, we have matrix K_F , K_B , K_C , K_D , meet $\left| f(x_1(t)) - f(x_2(t)) \right| \le k_f \left| x_1(t) - x_2(t) \right|$,

$\left| b(x_1(t)) - b(x_2(t)) \right| \le k_b \left| x_1(t) - x_2(t) \right|$,

$\left| c(x_1(t)) - c(x_2(t)) \right| \le k_c \left| x_1(t) - x_2(t) \right|$,

$\left| d(x_1(t)) - d(x_2(t)) \right| \le k_d \left| x_1(t) - x_2(t) \right|$.

Hypothesis 2.2.2: The initial conditions for nonlinear systems of $x_k(0)$, $x_d(0)$ meet $x_k(0) = x_d(0)$. Where $x_d(0)$ is the state variables in the k initial value, $x_d(0)$ is the initial expectation value.

Hypothesis 2.2.3: For the desired output for a given $y_d(0)$, the control algorithm.

$$\begin{cases} x_d(t+1) = f(x_d(t)) + b(x_d(t))u_d(t) \\ y_d(t) = c(x_d(t)) + d(x_d(t))u_d(t) \end{cases}$$

Where $x_d(t)$ and $u_d(t)$ are respectively the desired output and the desired state.

For the SISO linear system (1), the P type iterative learning control algorithm is as follows:

$$u_{k+1}(t) = u_k(t) + \eta\beta(t)e_k(t) \tag{5}$$

$\beta(t) \in \{0,1\}$, if $\beta(t) = 0$ indicates that the data lost. $\beta(t) = 1$ we know data integrity.

$P\{\beta(t) = 1\} = E\{\beta(t)\}$, $0 \le E\{\beta(t)\} \le 1$

Where η is the learning gain factor, $e_k(t) = y_d(t) - y_k(t)$ as the system tracking error.

Theorem 1: To meet the assumptions of nonlinear system 2.2.1-2.2.3 (4), (5) the learning control algorithm is iterative, when the system output data loss, for the learning gain factor η on the number and all the time the, and iterative k , we have:

$\left| 1 - \eta\beta(t)d(x_d(t)) \right| < 1$.

For any $t \in [0, N]$,

We know that $\lim_{k \to \infty} (y_k(t) - y_d(t)) = 0$

3. Results and Analysis

3.1. The Design of ILC-DO Control System

According to the demand of aeration tank of oxygen quantity, we using P-ILC algorithm to control the oxygen quantity. The P-ILC algorithm is used in the aeration tank of oxygen input link, can with the aeration tank of oxygen demand is very good, according to the amount of oxygen aeration tank and decided to give the amount of oxygen aeration tank input, and provide a theoretical basis for the energy saving our plan, and ensure that the aeration tank of oxygen is sufficient, the sewage treatment the highest efficiency.

Each input oxygen process, given a desired oxygen demand y_d, looking for the control input $u_k(t)$, made in the control of the actual input amount of oxygen, y_{k+1} and y_d. Considering the possibility of the actual operation, it can be considered, demand control input selection of aeration tank of oxygen, each input to the aeration tank of oxygen process, when the amount of oxygen input oxygen demand set arrived immediately closed oxygen input valve, the amount of oxygen and the desired trajectory of the input (i.e. setpoint) exist error: $e_{k+1} = y_{k+1} - y_d$,Where k is the input oxygen number. Figure 3 describes the structure and process of ILC control method.

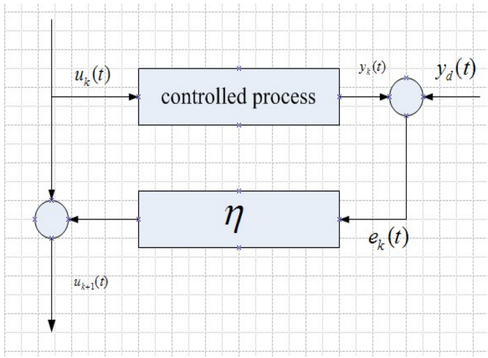

Figure 2. The Structure and Process of ILC Control Method

3.2. Simulation

We use the simulation hypothesis.

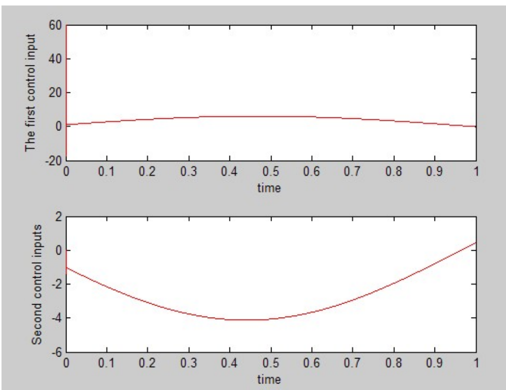

Figure 3. First and Second Control Input

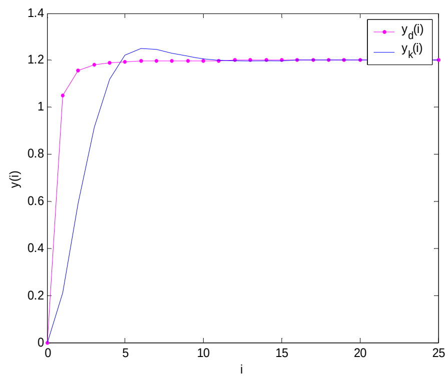

Figure 4. 20 Iterative Learning Control the Tracking Curve

Figure 3 is a first and a second control input (the amount of oxygen aeration tank required), Figure 4 for the twentieth iteration learning control algorithm tracking curve, we can see that after 20 iterations, the learning control, the target curve tracking, can completely control the number of oxygen in the aeration tank, this algorithm can control the oxygen effective. Figure 6 is the curve of error convergence curve, it can be seen that the algorithm will converge, the algorithm is proved to converge, the algorithm is reasonable.

4. Conclusion

(1) In order to make the sewage treatment efficiency is higher, the aeration tank of oxygen were analyzed, and the P-ILC algorithm is used in the aeration tank of oxygen input link, and according to the actual situation, considering the data generating omissions, adjusting the algorithm can completely control the aeration tank of oxygen.

(2) Through the simulation experiment to validate the model and its corresponding algorithm, the results as shown in Figure 4, shown in Figure 5, not only can the aeration oxygen demand good tracking, and can achieve perfect tracking oxygen demand goal after 15 regulation. More important is this algorithm may at any time according to need of aeration tank of oxygen supplement, when the lack of oxygen, can open the oxygen filling pump, when sufficient oxygen, close the oxygen filling pump, to achieve energy saving goals, ultimately makes the economic benefits to achieve the highest.

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References

[1] J Ferrer, MA Rodrigo, A Seco, et al. Energy saving in the aeration process by fuzzy logic control. *Water Science and Technology*. 1998; 38(3): 209-217.
[2] Ruey-Fang Yu, Shu-Liang Liaw, Cheng-Nan Chang, et al. Applying real-time control to enhance the performance of nitrogen removal in the continuous-flow SBR system. *Water Science and Technology*. 1998; 38(3): 271-280.
[3] Bongards M. Improving the efficiency of a wastewater treatment plant by fuzzy control and neural network. *Water Sci Technol.* 2001; 43(11): 189-196.
[4] A Puñal, E Roca, M Lema. System for monitoring and diagnosis of anaerobic wastewater treatment plants. *Water Research*. 2002; (36): 2656-2666.
[5] EF Carrasco, J Rodriguez, A Puñal, E Roca, JM Lema. Diagnosis of acidification states in an anaerobic wastewater treatment plant using a fuzzy-based expert system. *Control Engineering Practice*. 2004; 12(1): 59-64.
[6] Bongards M, Ebel Hilmer T. *Predictive control of wastewater works by neural networks*. Proceedings of the World Automation Congress. 2004; 17: 397-402.
[7] R Piotrowski, MA Brdys, K Konarczak, et al. Hierarchical dissolved oxygen control for activated sludge processes. *Control Engineering Practice*. 2008; (16): 114-131.
[8] Hao Xiaohong, Gu Qun, Xian Jun Du, Xu Weitao, Du Xianjun. Clonal Selection Algorithm Based Iterative LearningControl with Random Disturbance. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(1): 443-448.
[9] Sutikno, Tole. FPGA for robotic applications: From android/humanoid robots to artificial men. *TELKOMNIKA Telecommunication Computing Electronics and Control.* 2011; 9(3): 401-402.