

Research Article

Adaptive Fuzzy Control of Sludge Conditioning and Pressing

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The basic technological process of sludge conditioning and pressing is introduced in this paper. The purpose is to set up an adaptive fuzzy control algorithm to treat the problems of conditioning, mixing, feeding, and pressing control, so that the equipment used to process the sludge can run on demand. The algorithm is verified by MATLAB simulation. The results show that the control accuracy of the fuzzy adaptive control system is significantly improved compared with the original PID (proportion integration differentiation) control algorithm. The upper computer program is compiled with VB (visual basic) and applied to industry control to save the energy consumption.

1. Preface

Urban sewage treatment will inevitably produce sludge, and many harmful substances will remain in the sludge, so it is necessary to treat and dispose of excess sludge [1]; otherwise, it will pollute the environment. Sludge treatment and disposal follow the reduction, stabilization, harmlessness, and resource utilization. It is necessary to reduce the amount of sludge in the sewage treatment plant before connecting to the next stage [2]. It can be seen that dehydration and volume reduction are the most urgent needs at present, no matter what the disposal method is. The sludge conditioning and pressing technology is widely used and has become an important sludge dewatering treatment technology [3]. According to the needs of customers, the moisture content range after dehydration can be adjusted, and it has a very high degree of matching with various subsequent sludge disposal outlets. Due to the uncertainty of the organic matter content, moisture content, and process environment of the sludge drying treatment, the sludge volume and various parameters of the sludge quality of each batch are uncertain, resulting in the inconsistency of the sludge conditioning formula and control strategy [4]. Due to the lack of self-adaptive adjustment system, the current domestic process schemes often adopt the method of adding more chemicals and amplifying the insurance factor to standardize the water

content of the mud; however, it cannot realize the on-demand distribution of chemicals and process operations, which increase the operating costs. In addition, it is difficult to obtain an accurate mathematical model and control accurately for traditional method; there are many input parameters and control objects in the whole process system and still problems of nonlinearity and large time delay [5]. Therefore, a more reasonable and complicated algorithm needs to be proposed. The fuzzy adaptive control technology was used to dynamically control and adjust the feeding time, pressing pressure, and time in the filtering and pressing process [6], so as to realize on-demand operation, and achieve the goal of reducing the overall energy consumption of the system and saving operating costs. For uncertain nonlinear systems, indirect and direct adaptive fuzzy control (AFC) approaches have been intensively developed in the past decades [7]. Javanbakht and Chakravorty propose a new application of the prediction of human behavior using TOPSIS as an appropriate tool for data optimization [8]. Garg et al. presented a novel idea about the continuous possibilistic cooperative static game. The proposed Poss-CCSTG is a continuous cooperative static game (CCSTG) in which parameter associated with the cost functions of the players involves the possibility measures [9]. Bulut and Ozceylan developed a fuzzy inference system (FIS) to use six criteria as inputs, 144 rules were created, and the linguistic variables of air

textured yarn (ATY) samples of a textile manufacturer were used as well [10]. The quality level of the products according to the different membership functions is identified with the proposed FIS generated by MATLAB version 2015a, and recommendations are made to the manufacturer. Arora et al. use the Mamdani fuzzy inference system to predict COVID-19. The timely prognosis of the disease at home isolation or at the security checks can help the patient to seek the medical treatment as early as possible [11]. Chen et al. introduce the basic concepts of fuzzy theory and several common types of fuzzy application examples such as fuzzy washing machine and fuzzy control of incinerator plant in China illustrating the application of fuzzy theory in real society [12]. In this paper, for the uncertainty of pressure control in the process of sludge conditioning and pressing, an adaptive fuzzy control algorithm is proposed, and a control model is established to dynamically control and adjust the process of conditioning and pressing, so as to realize the operation of equipment on demand, and achieve the goal of reducing the overall energy consumption of the system and saving the operation cost.

2. Sludge Conditioning and Pressing Process

The residual sludge in the secondary sedimentation tank of the sewage treatment plant was used as analyte by the sludge conditioning and pressing process. [13]. The volume or weight of the sludge is reduced by two-thirds, and then, the remaining one-third of the concentrated sludge is reduced by more than 90% through the “chemical conditioning and pressing process,” and the sludge becomes a granules with moisture content less than 60% [14], which can initially reduce the amount of sludge treatment and reduce subsequent equipment investment and operating costs. After preconcentration, the sludge is quantitatively added with a suitable proportion of conditioner to improve the dewatering performance of the sludge, kill the pathogenic bacteria in the sludge and solidify the heavy metals in the sludge, and then press, and the moisture content of the pressed mud cake is below 60%. The corresponding sludge volume will be reduced by 8 to 13 times [15]. The mud cake can be disposed by various methods such as landfill, land use, and incineration. The entire process is shown in Figure 1.

In this process, the core equipment is the diaphragm filter press, which is composed of a filter plate and a filter frame with filtrate passages. It consists of five parts [16] as shown in Figure 2. A filter cloth is sandwiched between each group of filter plates and filter frames, and the filter plates and filter frames are pressed tightly with the movable end, so that a filter press chamber is formed between the filter plates and the filter frame. The sludge flows in from the feed liquid inlet, and the water flows through the filter plate out from the filtrate discharge port [17]. During this procedure, the filter cake will be squeezed and accumulated on the frame filter cloth. After the filter plate and the filter frame are loosened, the mud cake can be easily peeled off from the filter frame or removed from the filter cloth with a shovel.

Diaphragm filter press realizes a complete cycle of sludge deep dewatering procedure which mainly includes the following processes [18]: filling and filtration, diaphragm pressing, feeding hole core blowing, automatic pulling plate, and unloading cake, as shown in Figure 3. (1) Filling and filtration: the sludge is injected into all the filter chambers through the feeding pipeline. At the same time, the newly injected sludge squeezes the previous sludge to discharge the filtrate through the filter cloth. (2) Diaphragm pressing: after the feeding is finished, the extrusion medium (high pressure water) enters, and the diaphragm enters the filter chamber from the stop position under pressure. Through the movement of the diaphragm, the volume of the filter chamber is reduced, and the filter cake is squeezed and mechanically dried. (3) Core blowing in the feeding hole: use compressed air to blow the sludge in the feeding pipeline back to the feeding direction, so that the feeding hole and its surroundings are kept drying [19]. (4) Automatically pulling the plate and unloading the cake: the flap is opened, the hydraulic system drives the filter plate moving device to open the filter chamber one by one, and the filter cake is discharged into the downstream equipment.

In the actual production process, the key parameters of the machine are the pressing pressure and pressing time, which lead to the mud cake produced by the plate and frame filter press fulfill the criterion or not. If the pressing pressure is insufficient, no matter how long the pressing time is, the mud cake cannot fulfill the criterion [20]; if the pressing pressure is sufficient and the pressing time is not enough, the standard water content of mud cannot be produced. In terms of cost control, on the one hand, it is necessary to find a suitable pressing pressure to prevent it is too low to exceed the standard of mud production, further more causes energy waste in long-term pressing. On the other hand, when the pressing pressure is determined [21], it is necessary to find out appropriate pressing time, in order to achieve qualified water content of the mud, and the pressing time should not be too long to waste energy. In addition, if the water content of the sludge entering the diaphragm plate and frame sludge filter press is too high, in order to maintain the process stability, the dosing ratio of chemical additives must be slightly increased, thereby increasing the cost and the water content of the sludge, and the amount of mud entering the plate and frame will be increased too [22]. If the residence time of the leaching tank is shortened, the biological reaction is affected when the moisture content is too high, then the feeding needs to be completed within the specified time, and the flow rate of the sludge screw pump needs to be increased, which will inevitably increase the power of the sludge screw pump, thereby increasing the power consumption. In this paper, in order to keep the mud quality and conditioning conditions of each batch, the fuzzy adaptive control algorithm is used to dynamically control and adjust the feeding time, pressing pressure, and time of the filtration and pressing process, so as to realize on-demand operation, and achieve the goal of reducing the overall energy consumption of the system and saving operating costs [23].

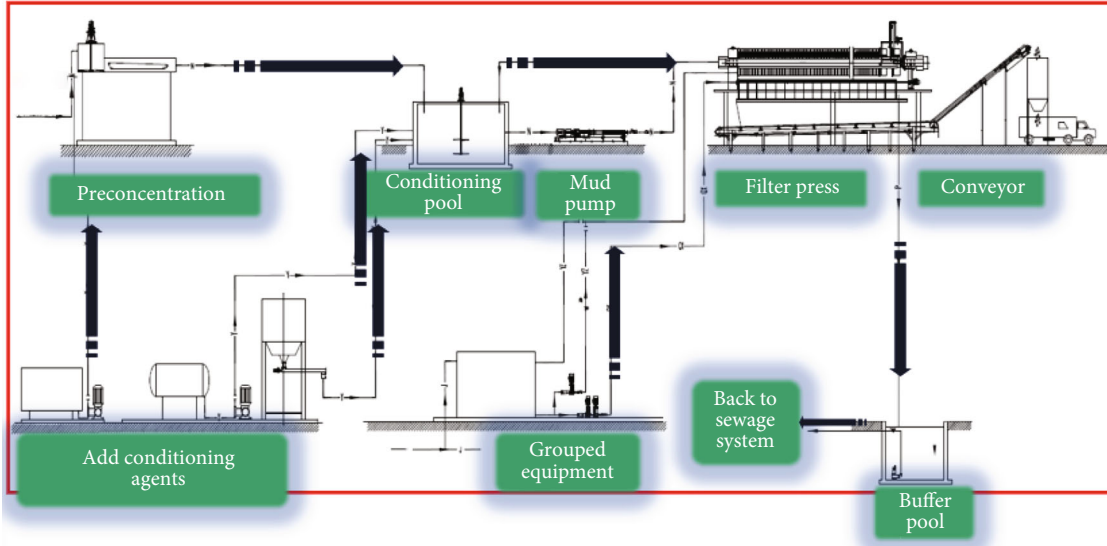


FIGURE 1: Sludge deep dewatering process flow chart.



FIGURE 2: Diaphragm filter press.

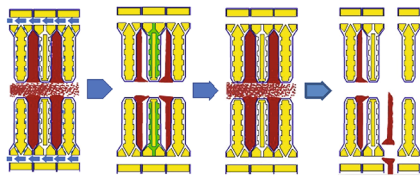


FIGURE 3: Sludge deep dewatering process.

3. Design of Fuzzy Adaptive Control Algorithm

In the early 1990s, Liu et al. proved that the fuzzy controller is a universal nonlinear approximator; that is, the fuzzy controller can realize the function approximation under arbitrary precision for any kind of continuous nonlinear equation defined under the density [24]. It is an important theoretical foundation for the universal application of fuzzy technology. In 1993, Yang et al. first proposed a stable adaptive fuzzy control method. Based on the Lyapunov function, they gave the adaptive rate of the parameters in the fuzzy system and strictly proved the stability of the control system. The derived closed-loop control system is globally stable,

and the tracking error of the system converges to zero asymptotically under the condition that the minimum approximation error is square integrable [25]. Yang et al.'s work has made a breakthrough in the research of adaptive fuzzy control theory. Under their promotion, the analysis methods of the stability, robustness, and control performance of fuzzy control systems have been developed rapidly. The stable adaptive fuzzy control method proposed by Yang et al. opens up a new way to study the control problems of unknown nonlinear systems with fuzzy logic systems.

3.1. System Description. Consider the object of study described by the following equation:

$$\begin{cases} \dot{x}^{(n)} = f(x, \dot{x}, \dots, x^{(n-1)}) + bu, \\ y = x. \end{cases} \quad (1)$$

In the formula, f is an unknown function, and b is an unknown constant. Direct adaptive fuzzy control uses the following IF-THEN fuzzy rules to describe the control knowledge:

$$\text{IF } x_1 \text{ is } P_1^r \text{ and } x_n \text{ is } P_n^r, \text{ THEN } u \text{ is } Q^r. \quad (2)$$

In the formula, P_i^r, Q^r is a fuzzy set in R , and $r = 1, 2, \dots, L_n$.

Suppose the position command is y_m ; make

$$e = y_m - y = y_m - x, e = (e, \dot{e}, \dots, e^{(n-1)})^T. \quad (3)$$

Choose $k = (k_n, \dots, k_1)^T$ so that all the roots of the polynomial $s^n + k_1 s^{(n-1)} + \dots + k_n$ lie in the left half-open of the complex plane. Because b in the system is uncertain, in order to ensure the stability of the fuzzy controller, another controller can be designed and added to the fuzzy controller to

maintain the stability, which is called the supervisory controller. Take the control law as

$$u^* = \frac{1}{b} \left[-f(x) + y_m^{(n)} + K^T e \right]. \quad (4)$$

Substitute equation (4) into equation (1) to obtain the equation of the closed-loop control system:

$$e^{(n)} + k_1 e^{(n-1)} + \dots + k_n e = 0. \quad (5)$$

Through the selection of K , when $t \rightarrow \infty$, $e(t) \rightarrow 0$, that is the output y of the system gradually converges to the ideal output.

Direct type fuzzy adaptive control is based on fuzzy system to design a feedback controller $u = u(x|\theta)$ and an adaptive law of adjusting parameter vector θ , so that the system output y can track the ideal output y_m as much as possible.

3.2. Design of Fuzzy Controller. The direct adaptive fuzzy controller is

$$u = u_D(x|\theta), \quad (6)$$

where is a fuzzy system and θ is a set of adjustable parameters.

The fuzzy system u_D can be constructed by the following two steps:

Step 1. For variable $x_i (i = 1, 2, \dots, n)$, define m_i fuzzy sets $A_i^{l_i} (l_i = 1, 2, \dots, m_i)$.

Step 2. Construct a fuzzy system $\prod_{i=1}^n m_i$ with the following $u_D(x|\theta)$ fuzzy rules:

$$\text{IF } x_1 \text{ is } A_1^{l_1} \text{ and } x_n \text{ is } A_n^{l_n}, \text{ THEN } u_D \text{ is } S^{l_1 \dots l_n}, \quad (7)$$

where $l_i = 1, 2, \dots, m_i$ and $i = 1, 2, \dots, n$.

A product inference engine, a single-valued fuzzer, and a center-averaged defuzzifier are used to design the controller.

$$u_D\left(\frac{x}{\theta}\right) = \frac{\sum_{l_1=1}^{m_1} \dots \sum_{l_n=1}^{m_n} y_u^{-l_1 \dots l_n} \left(\prod_{i=1}^n u_{A_i}^{l_i}(x_i) \right)}{\sum_{l_1=1}^{m_1} \dots \sum_{l_n=1}^{m_n} \left(\prod_{i=1}^n u_{A_i}^{l_i}(x_i) \right)}. \quad (8)$$

Let $y_u^{-l_1 \dots l_n}$ be a free parameter and put them in the set $\theta \in R \prod_{i=1}^n m_i$, respectively; then, the fuzzy controller is

$$u_D(x|\theta) = \theta^T \xi(x), \quad (9)$$

where $\xi(x)$ is a $\prod_{i=1}^n m_i$ dimensional vector whose l_1, \dots, l_n element is

$$\xi_{l_1 \dots l_n}(x) = \frac{\prod_{i=1}^n u_{A_i}^{l_i}(x_i)}{\sum_{l_1=1}^{m_1} \dots \sum_{l_n=1}^{m_n} \left(\prod_{i=1}^n u_{A_i}^{l_i}(x_i) \right)}. \quad (10)$$

The fuzzy control rule (2) is embedded in the fuzzy controller by setting its initial parameters.

3.3. Design of the Adaptive Law. Substitute equations (4) and (6) into equation (1), and get

$$e^{(n)} = -K^T e + b \left[u^* - u_D\left(\frac{x}{\theta}\right) \right]. \quad (11)$$

Make

$$\Lambda = \begin{pmatrix} 0 & 1 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 1 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & 0 & 1 \\ -k_n & -k_{n-1} & & & \dots & & -k_1 \end{pmatrix} b = \begin{pmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ b \end{pmatrix}. \quad (12)$$

Then, the closed-loop system dynamic equation (11) can be written in vector form:

$$\dot{e} = \Lambda e + b \left[u^* - u_D\left(\frac{x}{\theta}\right) \right]. \quad (13)$$

The optimal parameters are defined as

$$\theta^* = \arg \min_{\theta \in R_{r=1}^n m_i} \left[\sup_{x \in R^n} |u_D(x|\theta) - u^*| \right]. \quad (14)$$

The minimum approximation error is defined as

$$\omega = u_D(x|\theta^*) - u^*. \quad (15)$$

From formula (13), we can get

$$\dot{e} = \Lambda e + b(u_D(x|\theta^*) - u_D(x|\theta)) - b(u_D(x|\theta^*) - u^*). \quad (16)$$

From equation (9), the error equation (16) can be rewritten as

$$\dot{e} = \Lambda e + b(\theta^* - \theta)^T \xi(x) - b\omega. \quad (17)$$

Define the Lyapunov function:

$$V = \frac{1}{2} e^T P e + \frac{b}{2r} (\theta^* - \theta)^T (\theta^* - \theta), \quad (18)$$

where parameter γ is a positive constant.

P is a positive definite matrix and satisfies the Lyapunov equation:

$$\Lambda^T P + P \Lambda = -Q, \quad (19)$$

where Q is an arbitrary positive definite matrix $n \times n$ given by equation (12).

Take $V_1 = (1/2)e^T P e$ and $V_2 = (b/2r)(\theta^* - \theta)^T(\theta^* - \theta)$, let $M = b(\theta^* - \theta)^T \xi(x) - b\omega$, and then formula (17) becomes

$$\begin{aligned} \dot{e} &= \Lambda e + M, \\ \dot{V} &= \frac{1}{2}\dot{e}^T P e + \frac{1}{2}e^T P \dot{e} = \frac{1}{2}(e^T \Lambda^T + M^T) P e + \frac{1}{2}e^T P (\Lambda e + M) \\ &= \frac{1}{2}e^T (\Lambda^T P + P \Lambda) e + \frac{1}{2}M^T P e + \frac{1}{2}e^T P M \\ &= -\frac{1}{2}e^T Q e + \frac{1}{2} \left(M^T P e + \frac{1}{2}e^T P M \right) = -\frac{1}{2}e^T Q e + e^T P M, \end{aligned} \quad (20)$$

which is $\dot{V}_1 = -(1/2)e^T Q e + e^T P b [(\theta^* - \theta)^T \xi(x) - \omega]$ and $\dot{V}_2 = -(b/r)(\theta^* - \theta)^T \dot{\theta}$.

The derivative of V is

$$\dot{V} = -\frac{1}{2}e^T Q e + e^T P b [(\theta^* - \theta)^T \xi(x) - \omega] - \frac{b}{r}(\theta^* - \theta)^T \dot{\theta}. \quad (21)$$

Let p_n be the last column of P , it can be $e^T P b = e^T p_n b$ known from $b = [0, \dots, 0, b]^T$, and then, formula (21) becomes

$$\dot{V} = -\frac{1}{2}e^T Q e + \frac{b}{r}(\theta^* - \theta)^T [\gamma e^T p_n \xi(x) - \dot{\theta}] - e^T p_n b \omega. \quad (22)$$

Make adaptive law:

$$\begin{aligned} \dot{\theta} &= \gamma e^T p_n \xi(x), \\ \dot{V} &= -\frac{1}{2}e^T Q e - e^T p_n b \omega. \end{aligned} \quad (23)$$

Since $Q > 0$ and ω are the minimum approximation errors, by designing a fuzzy system $u_D(x|\theta)$ with enough rules, ω can be made sufficiently small and satisfy $|e^T p_n b \omega| \ll (1/2)e^T Q$, so that $\dot{V} < 0$.

The structure of the direct adaptive fuzzy control system is shown in Figure 4.

3.4. Simulation Discussion. The simulation of sludge conditioning and pressing can generally be defined as a first-order inertia plus pure lag link model. The sludge screw pressing process is affected by the fluctuation of sludge concentration, the different viscosity of materials in the wastewater, the structural characteristics of variable pitch and diameter, and the dewatering process. Therefore, the control system of the dewatering machine is nonlinear and time-lag, which can easily lead to the blockage of the dewatering machine and the unstable concentration of the discharged sludge.

This paper studies the sludge dewatering process and designs an adaptive fuzzy control algorithm suitable for sludge dewatering. The transfer function of the controlled object and the disturbance channel is $P_1 = P_{d1} = e^{-10s}/100s + 1$ and $P_2 = P_{d2} = 2e^{-2s}/20s + 1$. The input pressure is $x_d(t)$

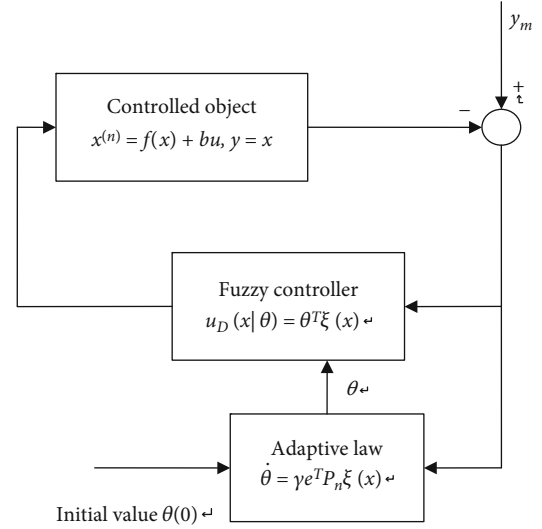


FIGURE 4: Direct type adaptive fuzzy control.

$) = \sin(t)$. Take the following five membership functions to fuzzify the input x_i of the fuzzy system: $\mu_{NM}(x_i) = \exp[-((x_i + \pi/3)/(\pi/12))^2]$, $\mu_{NS}(x_i) = \exp[-((x_i + \pi/6)/(\pi/12))^2]$, $\mu_Z(x_i) = \exp[-(x_i/(\pi/12))^2]$, $\mu_{PS}(x_i) = \exp[-((x_i - \pi/6)/(\pi/12))^2]$, and $\mu_{PM}(x_i) = \exp[-((x_i - \pi/3)/(\pi/12))^2]$. Then, there are 25 fuzzy rules for approximating f . According to the membership function design program, the membership function diagram can be obtained, as shown in Figure 5.

After analyzing the input and output characteristics of the actual control system, it is concluded that the transfer function of sludge conditioning and pressing is approximated as a first-order inertia plus pure lag link model. The step response curve of the above fuzzy control system is shown in Figure 6. For analysis and comparison, the control effect of the above system and the traditional PID control effect are placed in a coordinate system. From the system simulation curve, the system response curve of the PID controller has overshoot and the transition time is relatively long, while the system response curve of the fuzzy controller is relatively stable and has no overshoot.

Using the adaptive fuzzy algorithm above, real-time control is realized by computer. According to the deviation and the fluctuation, the fuzzy control rules are used to determine the electrical output, so as to obtain a good control effect, which has the following characteristics:

- (1) Compared with the control effect of the ordinary PID controller, the system response overshoot is small after the adaptive fuzzy controller is adopted, and the response curve is stable
- (2) The system has good response speed, stability, and accuracy and has strong robustness
- (3) The three parameters determined by the fuzzy control rules are dynamic, which is more in line with the control characteristics of the system

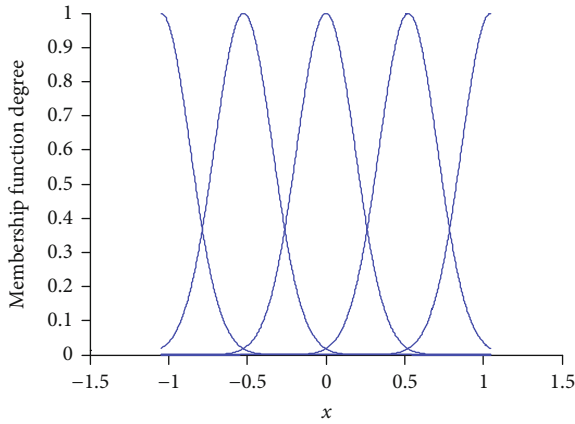


FIGURE 5: Membership function of x_i .

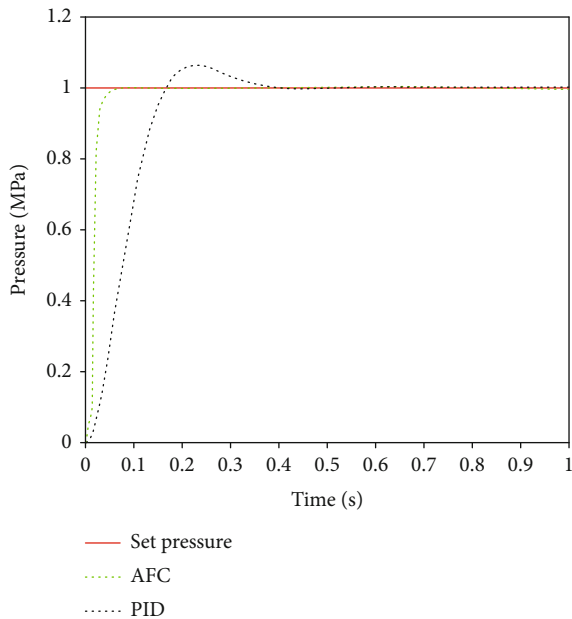


FIGURE 6: Pressure control response curve.

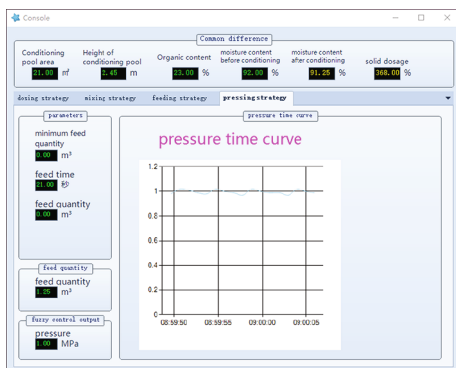


FIGURE 7: Press interface and time pressure curve.

4. Control System Composition

The adaptive fuzzy control algorithm of this project is developed by the host computer using high-level language programming. The entire control system consists of two parts: measurement and control subsystem and execution subsystem. The measurement and control subsystem is responsible for completing the collection of on-site data and generating dynamically adjustable dosing amount and feeding pressure according to the adaptive fuzzy control algorithm and sends the speed regulation command to the frequency converter for control. The execution subsystem is composed of PLC and control motor, to communicate between fuzzy control software and field PLC through standard Ethernet communication protocol.

The main pressure control is divided into feeding control and pressing control. Generally, the feeding pressure shall not exceed 0.45 MPa, and the thickness or volume of the filter cake formed by the feeding shall not exceed the specified value.

4.1. Feed Control Strategy. Collect the organic substance content of each batch after treating the sludge, and calculate the feed volume according to the measured sludge moisture content, dosing amount, and the water content of the batch of sludge after dosing. The feeding time is set (usually 90 minutes), and the adaptive fuzzy control is used for subfeeding according to the actual feeding pressure, and the feeding pressure is automatically adjusted to reduce the energy consumption of the system. Input the parameters required by the system: minimum feeding amount, feeding time, feeding material, running time, and other parameters. The fuzzy control system will output the segmented feeding control pressure according to the input parameters.

4.2. Squeeze Control Strategy. By monitoring the liquid level of the conditioning tank in real time, when the liquid level drops to the set value after the feeding is completed, the water content of the sludge after dosing can be used to calculate the liquid level that needs to be lowered in the conditioning tank. The amount of material to choose the controlled pressing pressure and pressing time, to control the press, and the pressure control curve is shown in Figure 7.

In the process of sludge adjustment and pressing, the traditional PID automatic control mode and adaptive fuzzy control mode are used to control the operation of the sludge treatment equipment, and the power consumption during the operation of the equipment is evaluated and compared. The power consumption of the equipment mainly includes sludge feeding process, conditioning process, pressing process, and sludge conveying process. The comparative analysis is shown in Table 1.

According to the statistics in the above table, when the complete set of sludge treatment equipment is operated under the traditional PID control mode and the adaptive fuzzy control mode, except for the sludge conveying system, the latter save nearly 11% of the total cost of electricity.

TABLE 1: Comparative analysis of power consumption.

Category	Technological process	PID control	Adaptive fuzzy control	Saving ratio
Power consumption (kW·h/batch)	Sludge feeding	0.60	0.52	13.3%
	Conditioning	8.02	7.14	11.0%
	Press	7.6	6.72	11.6%
	Sludge transportation	0.80	0.80	0.0%
	Total	17.02	15.18	10.8%
Electricity cost (RMB yuan/t)	Total	18.24	16.26	10.9%

Note: the unit price of electricity is calculated as 0.75 yuan/kw · h, the treatment capacity of each batch is calculated as 0.70 t, and the sludge volume is calculated as 80% moisture content.

5. Summary

In this paper, the design and implementation of an adaptive fuzzy control system for the sludge conditioning and pressing process is completed, which is superior to the traditional PID control method. Fuzzy control is controlled according to the experience of experts, the control is intelligent and flexible, and it can control the system in real time accurately. The control process is simple and effective. Compared with the traditional controller, it has the advantages of small overshoot and small steady-state error. And for different control objects, without changing the parameters, all achieved better control effect. Through real-time dynamic detection and self-adaptive control of each batch of sludge volume and mud quality and use of fuzzy expert control technology to establish a control model to dynamically control and adjust the conditioning process, the equipment can be operated on demand, so as to reduce the overall energy consumption of the system and save energy. With the continuous in-depth research and development of fuzzy control technology, it will definitely open up new application prospects for industrial process control, environmental protection, and control in the fields of sewage sludge.

This paper studies the self-adaptive fuzzy control method of sludge conditioning and pressing in sewage plant, in order to reduce production energy consumption. On the other hand, the historical data of the operation of the sewage treatment system is accumulating, and many important information is hidden behind these data. It is important to understand the hidden knowledge, potential relationships, and rules behind the data from a large number of highly coupled historical data. In the next step, we will deeply study the coupling relationship between dissolved oxygen and total sludge, combine the control of dissolved oxygen with the control of total sludge, and then study the sludge reduction control method in the sewage treatment process.

Data Availability

All data, models, and code generated or used during the study appear in the submitted article.

Conflicts of Interest

The author declares no conflicts of interest.

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