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Optimize electric automation control using artificial intelligence (AI)

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ABSTRACT

To successfully address the issues confronting current electrical engineering, a control system based on artificial intelligence technology is designed. The paper presents a model of an electrical automation control system based on an artificial intelligence algorithm. The control parameters are optimized by implementing a control method based on an artificial intelligence algorithm. The research findings indicate that when 20 % load interference and 2.1 Hz frequency interference are present, the turbine's highest failure rate under system control is 0.02, showing that the system has a good anti-interference capability. As a result, the use of artificial intelligence algorithms for autonomous control of electrification can significantly increase control reaction time, reduce costs, and produce more efficient production.

1. Introduction

Artificial intelligence has been widely investigated and popularized across a range of industries, most notably in the field of electrical automation control, assisting in the progress of electrical automation. Electronics, telecommunications, computers, and other professions and disciplines readily combine information and intelligent content with AI technology. It can be used to mimic human consciousness or thinking in a wide range of situations. Because AI technology has computer advantages, such as the ability to perform precise control operations, reduce reliance on human interaction, and efficiently prevent avoidable human-factors-caused errors, its use in related industries could significantly increase the level of intelligence in these industries [1,2]. In electrical automation control technology, artificial intelligence technology has become a core part of electrical automation technology research and application [3]. Social development makes economic production increasingly dependent on scientific and technological progress, whether in agriculture, industry, or tertiary industry, has been widely used in electrical automation control technology. Computer, sensor, and GPS technology are all used in artificial intelligence. Intelligent technology is used in industrial production, which reduces employee work intensity, increases enterprise production efficiency, and successfully lowers production costs, making businesses more competitive in the market [4]. Artificial intelligence technology, in particular, can dramatically reduce the risk of injury to workers in dangerous environments. Artificial intelligence technology can reduce unit costs and labor costs in industrial and agricultural production, as well as improve operation accuracy. By minimizing manual operations, the safety of production activities is effectively improved, as well as production efficiency and enterprise benefits [5]. Machine learning has increased the capability and scope of electrical engineering optimization, resulting in significant cost, safety, and real-time operation control improvements [6]. The author offers a robust adaptive technique based on pseudo-fuzzy logic and sliding mode control (PFSMC). The suggested control algorithm can not only guarantee the system's stability, but also improve the steady-state tracking error, To show comparison answers in a computer context,

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two controllers are used to implement test cases with and without assurance. The use of artificial intelligence technology in an electrical automation control system can successfully increase the level of control and, as a result, modernization and intelligence[7,8].

In the electrical sector, electrical automation control is extremely important; if electrical control automation is achieved, production efficiency may be effectively improved, cutting production costs, including human resource expenses [7,8]. In electrical automation control, artificial intelligence technologies such as fuzzy control, expert systems, neural networks, and other artificial intelligence technologies are used. In the growth of automation, artificial intelligence can not only promote overall progress in the field of electrical automation control, but it can also promote the growth of automatic control of progress, so in the field of electrical industrial applications, innovation necessitates the use of artificial intelligence technology to improve mechanical ability consciousness and strengthen electrical automatic control [9,10]. In this paper, the manual technique used in electrical automation control is examined. The ability to control electrical automation in an efficient and precise manner is crucial. Automation control focuses on computer data processing applications, data classification and identification processing, system composition structural optimization, and electrical automation control, as well as all small branches [11]. The work efficiency of electrical automation control will be greatly improved to some extent by combining automation control technology with artificial intelligence algorithm, saving time in traditional electrical control, reducing energy and human resources consumed in equipment operation, greatly improving machine time and control accuracy of electrical automation control [12,13]. Based on the joint learning framework, Shi M. and colleagues suggested a clone selection optimization method. Joint training effects were optimized using the heuristic clone selection technique in local model optimization[14–16]. To begin, the procedure enhances the federated learning solution's adaptability and robustness, as well as the modeling performance and training efficiency [17,18]. Furthermore, through differential privacy preprocessing, this research aims to increase the privacy security defensive capability of federally funded learning programs. Simulation results suggest that the combined learning-based clone selection optimization system may significantly improve the model's fundamental performance, stability, and privacy [19].

Automation of a large electrical power distribution network by a single controller can improve efficiency and reliability while lowering maintenance costs. The controller must have a general picture of the entire network in order to reason about the cause of the readings from the many sensing devices positioned across the network for the control to be most successful. Traditional power system control relies on a network of local devices making decisions based on a single sensor's immediate reading. Sensor faults can cause these single-parameter results to be inaccurate [20,21]. On the basis of this, an artificial intelligence-based electrical automation control system model is developed. The control effect of the system is better than the traditional PD control system when there is 20 % load interference and 2.1 Hz frequency interference, and under the control of the system, the output frequency fluctuation of the turbine system is small, fast convergence to the optimal frequency, and under the control of the system in this paper, the maximum failure rate of the turbine is 2 %. Artificial intelligence algorithms may considerably increase the automatic control of electrification's control reaction time, save money, and achieve efficient production in the automatic control of electrification.

2. Research methods

2.1. Electrical automation control system based on artificial intelligence algorithm

(1) Hardware Design

Electrical automation control system based on artificial intelligence algorithm is around the turbine regulation, as the goal, through a single neural network based PD intelligent controller module, based on the adaptive ant colony genetic artificial intelligence algorithm, the optimal control of PD intelligent controller is realized.

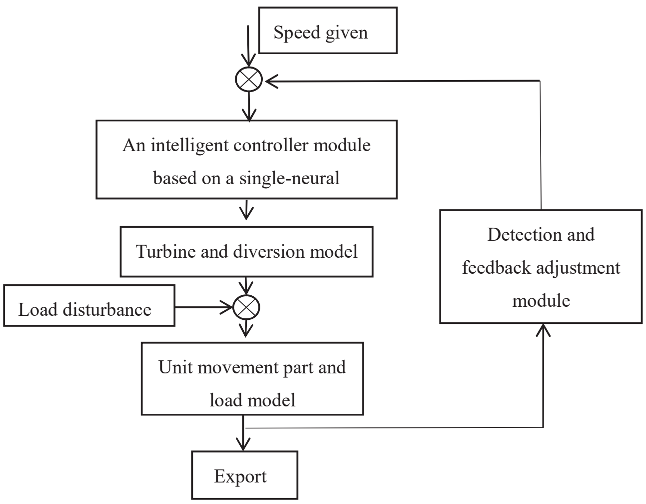


Fig. 1. Structure of electrical control system based on artificial intelligence algorithm.

(2) System structure

The core components of the system include water turbine, pressure water inlet, and large motors, among which, PD intelligent controller module based on a single neural network is included, which belongs to the feedback control system. The structure diagram of the electrical automation control system based on artificial intelligence algorithm is shown in Fig. 1. In Fig. 1, (a) represents a given rotational speed signal, (b) represents the output control signal, and (c) represents the load disturbance signal, for a parallel operating unit, its output power variation does not interfere with the frequency of the power system, based on this kind of situation, the function of the turbine regulating feedback system is 0, in this case, the PD intelligent controller module based on single neural network can enable the follow-up system function. Fig. 1 illustrates that, the turbine governor has experienced the development process from mechanical hydraulic governor to the process of analog circuit to microcomputer electro-hydraulic governor. Prior to the appearance of the microcomputer governor, the main mission of the governor (mainly machine governor and analog circuit governor) was to adjust the water guide mechanism / paddle mechanism (injection needle / converter mechanism) according to the unit frequency deviation of the rating, and the turbine governor is mainly a speed regulator.

(3) intelligent controller module based on single neural network

The core of intelligent controller is a single neuron, which can complete self-learning, has good adaptability, and the structure is simple, can quickly adapt to the nearby environment, the field adjustment parameters are few and easy to adjust, which can ensure that the control system belongs to the optimal state in practical application, its control effect is better than ordinary controller. Based on using a single neuron, the adaptive controller can play a better role. For the converter input, it can make the turbine controlled process and control settings can be optimized, such as setting S (r), the output can be transformed into the number of relevant states required in neuron-based learning control, in the state coefficient Y_1, Y_2, Y_3 of the output of the converter, $Y_1(r)$ is equal to $\varphi(r)$, $Y_2(r)$ operates on $\varphi(r) - \varphi(r-1)$, $Y_3(r)$ operates on $\varphi(r) - 2\varphi(r-1) + \varphi(r-2)$, S describes the performance index, R describes the neuron proportional coefficient, neurons using association retrieval can derive control signals H_p , H_i , H_d, then the control strategy of artificial intelligence algorithm is used to realize the optimal adjustment control of three kinds of control signals, that is, the three kinds of control parameters.

2.2. Control strategy based on artificial intelligence algorithm

(1) Node and Path generation

Set H_p,H_i,H_d as the three variables to be set in the PD, controller suppose there are five significant digits for each of the three variables. Set the 5 digits of H_p , H_i , H_d according to the value condition in the PD controller. 1 place before the decimal point and 4 places after the decimal point for example, 1.0025. Then the ant path graph is optimized according to the ant colony algorithm with this parameter. For these three parameter values, they are abstractly described in the xOy plane, the method is to draw 15 equally spaced and equally long line segments $A_1, A_2, \ldots, A_{15}$ perpendicular to the X-axis, among them, $A_1 \sim A_{15}$, $A_6 \sim A_{10}$, $A_{11} \sim A_{15}$ describes the first to fifth digits of H_p , H_i , H_d in turn. Divide each line segment equally, that is, obtain 10 nodes from each line segment and describe the digit values represented by the line segment in turn. Therefore far, there are 15×10 nodes in the xOy plane, and set 1 node as $a(x_j, y_{j,i})$, where, x_j describes the x-coordinate of line segment A_j; $y_{j,i}$ describes the ordinate of node i on A_j, and the value corresponds to the ordinate value $y_{j,i}$ of the node. Suppose an ant starts at the origin O, and after crawling to a random point in segment A_j, implement a loop, and its crawling path can be described as $B = \{O, a(x_1, y_{1,i}), a(x_2, y_{2,i}), \ldots, a(x_j, y_{j,i})\}$, where $a(x_j, y_{j,i})$ node is in line segment A_j, then the value described by this path is shown in Formula (1):

$$\begin{cases} H_p = y_{1,i} \times 10^0 + y_{2,i} \times 10^{-1} + y_{3,i} \times 10^{-2} + y_{4,i} \times 10^{-3} + y_{5,i} \times 10^{-4} \\ H_i = y_{6,i} \times 10^0 + y_{7,i} \times 10^{-1} + y_{8,i} \times 10^{-2} + y_{9,i} \times 10^{-3} + y_{10,i} \times 10^{-4} \\ H_d = y_{11,i} \times 10^0 + y_{12,i} \times 10^{-1} + y_{13,i} \times 10^{-2} + y_{14,i} \times 10^{-3} + y_{15,i} \times 10^{-4} \end{cases} \tag{1}$$

(2) Algorithmic control process

The control process based on artificial intelligence algorithm is as follows:

1) According to the parameter tuning method, namely Z-N method, the calculated PD parameter is $H_{p,s-M}, H_{i,s-M}, H_{d,s-M}$
2) The number of ant colonies is n, and each ant h has 15 ordinate values and crawling path attributes that are used to store the 15 nodes passed by ants.
3) Hybrid algorithm parameter initialization: put the ant at the starting point.
4) Set the value of variable j to 1, if the parameter $p < p_0$, then calculate the probability $Q_{ji}^h(t)$ of ants transferring each node in line segment A_j by formula (2); On the contrary, formula (3) is used to select the subsequent nodes through the wheel selection method, and the value of this node is introduced into the Table. As shown in Eq. (2)

$$\delta(t) = \begin{cases} 0.95\delta(t-1), 0.95(t-1) \geq \delta_{\min} \\ \delta_{\min}, else \end{cases} \tag{2}$$

Where $\delta(t)$ describes local pheromone parameters. As shown in Eq. (3)

$$Q_{ji}^{h}(t)=\begin{cases}\dfrac{[\psi_{ji}(t)]^{1}\cdot[\vartheta_{ji}(t)]^{2}}{\sum_{h\in allowed_h}[\psi_{ji}(t)]^{1}\cdot[\vartheta_{ji}(t)]^{2}}, i\in allowed_h\\ 0, else\end{cases} \tag{3}$$

Where: *allowed*$_h$ describes the nodes that ant h can select next; $[\vartheta_{ji}(t)]^2$ describe the importance of visibility factors; $[\psi_{ji}(t)]^{-1}$ describes the importance of pheromone locus intensity.

5) When each ant finishes a node, Eq. (4) is adopted to refresh the local pheromone, and the local information volatility coefficient is adaptively transformed. As shown in Eq. (4)

$$\psi_{ji}\leftarrow(1-\delta)\cdot\psi_{ji}+\delta\cdot\Delta\psi_{ji} \tag{4}$$

Type: $\Delta\psi_{ji}=\frac{P_1}{S_{PID1}}$, S_{PID1} describe the node path passed; the value of local pheromone parameter δ is adaptive. $\Delta\psi_{ji}$ Describe the track pheromone intensity per unit length.

6) Set j=j+1, if the value of j is not greater than 15, jump to Step 3), otherwise, jump to Step 7).
7) Following the path that the ant h has climbed (array G_h), Calculate the PD parameter H_p^h , H_i^h , H_d^h corresponding to this path；Implement computer simulation to obtain the performance index s_z^h of the system, steady-state adjustment error d^h and overshoot e^h; Calculate the corresponding objective function of ant h, record the best path and the best performance index in this cycle, and lead H_p^h , H_i^h , H_d^h into H_p^* , H_i^* , H_d^*。
8) Assuming$h\leftarrow h+15$, all pheromones are refreshed according to Eq. (5), and the volatiles coefficient of all information is adaptively adjusted. As shown in Eq. (5)

$$\psi_{ji}\leftarrow(1-\partial)\cdot\psi_{ji}+\partial\cdot\Delta\psi_{ji} \tag{5}$$

Where ∂ describes the volatilization coefficient of all pheromones.

9) Use the single point crossing strategy to cross (cross when crossing constraint variable$\theta<0.000001$) and generate new individuals.
10) Using the basic mutation (mutation occurs when crossing the constraint variable $\theta<0.01$) scheme, calculate each parameter value again , if the performance index obtained is close to the objective function F, so if the mutation is not removed, the pheromone is uated, and conversely, the mutation is removed.
11) If all ants do not converge to the same path, put all ants at the starting point again and jump to the step, otherwise, the loop stops and outputs the optimal path and the corresponding optimal PD parameters H_p^* , H_i^* , H_d^*.

2.3. Functions of the electrical automation control system

The function of the electrical automation control system is control; the premise of the control function is to analyze the data to provide a control basis. ·

(1) Information collection. The electrical system is required to have relevant data terminal collection and software equipment; the main function of information collection is to provide a basic guarantee for the realization of the control function [22]. Terminal equipment and software are used to collect equipment, operation, and environment in the power system，it mainly includes operation time, equipment quantity, ambient temperature, fault condition, alarm system and signals, etc. using the data collected by the software and equipment with real-time information on the power system to provide operational information for the staff, so that the staff can effectively deal with the emergency;
(2) Information transmission. Information is two-way transmission, that is, terminal equipment and software collect information to the processing center for transmission, and the processing center is the transmission of control processing instructions to the execution terminal [23,24]. Therefore, the process of information transmission is particularly important, and information transmission is also the main condition to realize the control and supervision of the control system. Transmission equipment of power system mainly includes video cable, signal cable, coaxial cable, optical cable, etc. ，the corresponding transmission mode can be selected according to transmission distance and type，to ensure the quality and speed of information transmission, to avoid information loss, the transmission is not timely, coding disorder and information confusion [25]. The controller is required to include a control module, power module, communication module, editing module, etc., to ensure the coordination of the system;
(3) Information analysis. Information analysis refers to the main process of control and monitoring of the control system，the control system should process and analyze the information collected by terminal equipment and software，after the collected information is sent to the database, the control system and software are displayed, and the system cannot be handled independently by the staff to use the system to help achieve the corresponding work [26]. In addition, the system should collect data to achieve storage, including the environment, equipment, and other real-time data, which can be printed through graphs, reports, etc., to facilitate staff analysis;
(4) Diagnostic control. Diagnostic control belongs to the main function of electrical automation control system，after information collection and analysis, the control system should be able to diagnose autonomously，based on the analysis results, including computer, controller, field terminal equipment diagnosis, so that the system can run stably [27–31]. In addition, the analysis

and diagnosis results to achieve control including power system fault detection, operation detection, so that the power system can operate stably.

3. Result analyses

The electrical automation system is more complex, including many disciplines and fields. For example, in terms of electrical automation equipment operation, the operators are required to have good comprehensive quality and perfect professional knowledge. In addition, the complexity of electrical automation focuses on operational effectiveness, which can reduce the shutdown or other accidents caused by operation errors or improper operation. Therefore, AI technology plays an important role in facing this real problem. Take the computer theory as the basis, write a program, can realize the computer-based intelligent control. Intelligent operation of electrical equipment can replace the problem of insufficient human brain labor force. Not only improve work efficiency, but also reduce cost input. In addition, the use of artificial intelligence technology can improve the scientific operation of electrical automation equipment, and realize the optimization of the real environment of equipment operation. The system is used in a hydropower station to realize the optimal PD control of the turbine in the hydropower station. Single machine set the isolated load, set two types of working conditions, working condition A is the design head rated power work; working condition B is the design head, working with partial load. Unit parameters: Runner model IS HL220-LJ-410; Single unit capacity is 102.7 MW; the hydrodynamic inertia time constant is 1.11 s, and the unit inertia time constant is 6.66 s. The parameters of the traditional PD control system are set as Hp=4.04, Hi=1.23, Hd =2.67. The parameters of the turbine system in the experiment are shown in Table 1.

In working condition A, under the control of the system and the traditional PD control system, the response curve of the turbine system subjected to 20 % load interference and 2.1 Hz frequency interference is shown in Fig. 2 ; In working condition B, under the control of the system and the traditional PD control system, the response curve of the turbine system subjected to 20 % load interference and 2.1 Hz frequency interference is shown in Fig. 2. Analysis of the control results in Fig. 2 and Fig. 3 shows that: The control effect of the system in this paper is better than that of the traditional PD control system. Under the control of the system in this paper, the output frequency of the hydraulic turbine system fluctuates less and converges quickly to the optimal frequency. The output frequency of the hydraulic turbine is stable at about 20 s and remains at 0.000–0.005 between; under traditional PD control, the output frequency of the hydraulic turbine system fluctuates greatly, especially in 20–40 s, the output frequency of the hydraulic turbine fluctuates up and down, and it can converge to the optimal frequency when the experiment takes about 50 s. It can be seen that the control effect of the system in this paper is the best.

When 20 % load interference and 2.1 Hz frequency interference are tested, the failure rate of the turbine is shown in Fig. 4 after the system control is adopted. In Fig. 4, the maximum failure rate of the turbine under system control is 0.02 for both 20 % load interference and 2.1 Hz frequency interference, indicating that the system in this paper has high anti-interference performance.

Set the input of the turbine system as a unit step signal. Set the number of ants to 30 and the number of iterations to 100. The range of PD control parameters is: Hp=Hd= [0.00001 , 20], it is compared with PLC electrical automation control system and electrical control system of conveyor controllable variable speed device. Fig. 5 is the PD step response diagram of the turbine system under the control of three kinds of systems.

Table 2 shows PD tuning parameters and system unit step performance indicators. Based on the data in Fig. 5 and Table 2, it can be seen that the two PD parameters of the system control have the best effect. Compared with the other two systems, the adjustment time of the turbine system is only 10.05, while that of the other two systems is 36.25 and 16.24 is much higher than the system. The steady state adjustment error and the number of overshoots are only 0.1677 and lower than the other two systems. Therefore, the system control performance is best.

4. Discussion

The function of electrical automation control system is control, and the premise of the control function is to analyze the data to provide the control basis. (1) Information collection. The electrical system is required to have corresponding data terminal collection and software equipment, and the main function of information collection is to provide the basic guarantee for the realization of the control function. The terminal equipment and software are used to collect the operation and environment of the equipment in the power system, mainly including the operation time, equipment quantity, environmental temperature, fault situation, alarm system and signal, etc. Use the data collected by the software and equipment to provide operation information to the real-time information in the power system, so that the staff can effectively handle emergencies; (2) information transmission. Information is two-way transmission, that is, the terminal equipment and software collect information to the processing center for transmission, the processing center is to control the processing instructions to the execution terminal transmission. Therefore, the information transmission process is particularly important, and the information transmission is also the main condition for the control and supervision of the control system. Power system transmission equipment mainly includes video cable, signal cable, coaxial cable, optical cable, etc., to choose the corresponding transmission mode by transmission distance and model type, to ensure the quality and speed of information

Table 1
Parameters of the turbine system in the experiment.

Parameter	Working condition of A	Working condition of B
Turbine transfer coefficient 1	-0.29	-0.25
Turbine transfer coefficient	0.71	1.05
Turbine transfer coefficient	1.26	0.82
Turbine transfer coefficient	0	0
Turbine transfer coefficient	0.78	1.07
Turbine transfer coefficient	0.34	0.32
Generator self-adjusting coefficient	0.21	0.21

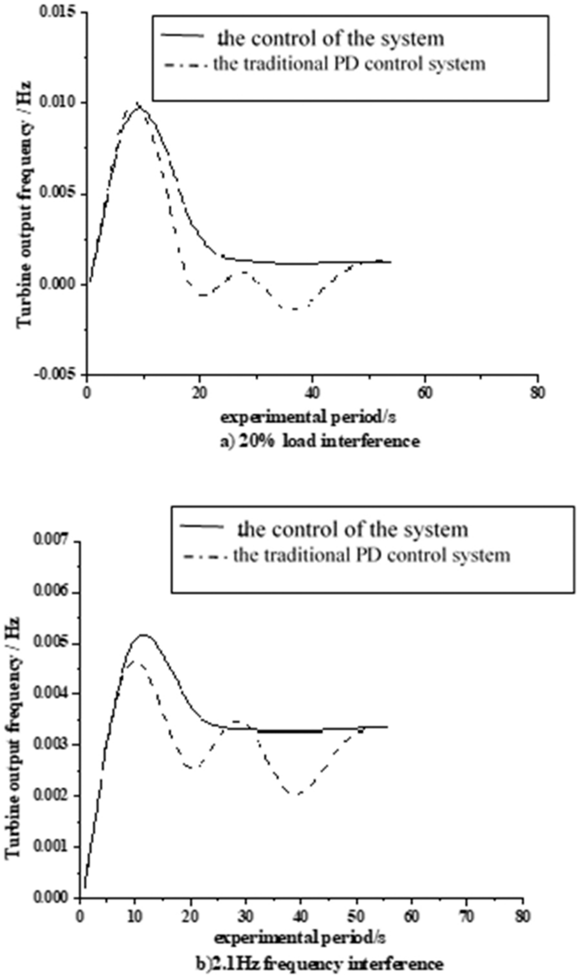
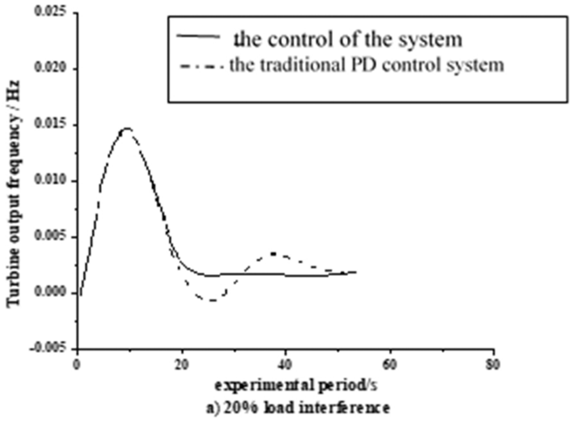


Fig. 2. Comparison of control effects under working condition A.

transmission, to avoid information loss, untimely transmission, coding confusion and information confusion. The controller is required to include the control module, power supply module, communication module, editing module, etc., to ensure the working coordination of the system. The control results of Figs. 2 and 3 show that the control effect of the system is better than the traditional PD control system, and the output frequency of the turbine system fluctuates less and quickly converges to the optimal frequency. Under the traditional PD control, the output frequency of the turbine system can converge to the optimal frequency at about 50 sTherefore, the system controls the best.

5. Conclusions

Under the background of the rapid development of modern science and technology, our life has been changed, artificial intelligence technology has promoted the development of modern civilization, as a new high technology, it has high use value in real life. Design an electric automation control model optimization based on artificial intelligence algorithm, and apply it in the experiment, after testing in different working conditions, when there is 20 % load interference and 2.1 Hz frequency interference, the control effect of the system is better than the traditional PD control system, under the control of the system, the output frequency of the turbine system fluctuates less, converges quickly to the optimal frequency, and has high robustness, it is predicted that the future electrification industry will inevitably rely on artificial intelligence algorithm. In the automatic control of electrification, the application of artificial intelligence algorithm can greatly improve the control reaction time of the automatic control of electrification, save cost, and achieve efficient production. Therefore, the application of artificial intelligence algorithms is very broad. The application of AI technology to electrical automation control systems is crucial to the development of various fields. At present, the electrical automation control system has been widely used in intelligent buildings, and has achieved certain application results. When creating the electrical automation control system, people must fully consider the actual requirements, use appropriate methods to calculate the automatic control system parameters, and actively use artificial intelligence technology to improve the effect of electrical automation control. The design and development of electrical automation control system must analyze the working environment interfering with the



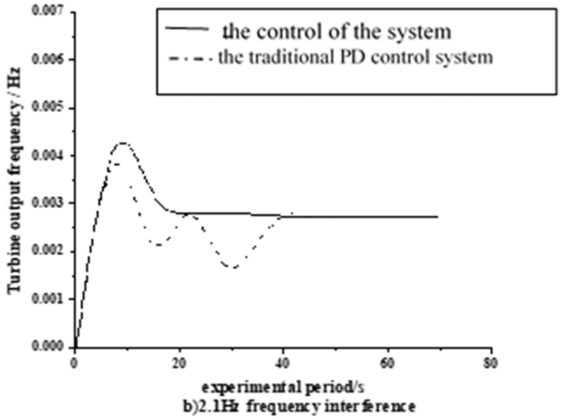


Fig. 3. Comparison of control effects under working condition B.

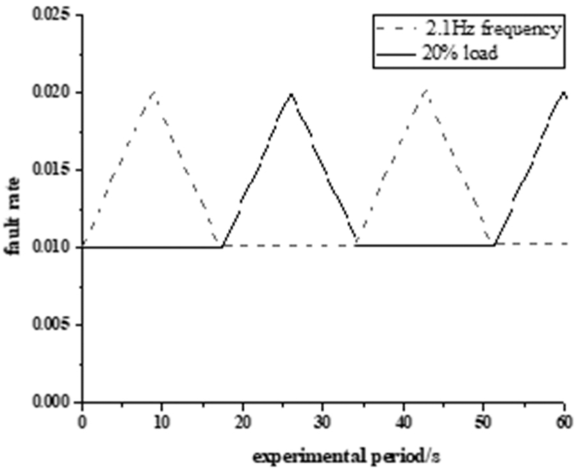


Fig. 4. Failure rate of hydraulic turbine controlled by the system in this paper.

operation of equipment and the operation of equipment, and pay great attention to the interference of external environment during design. In addition, to ensure that the system can complete a stable power transmission, based on the system research and development and design cycle, the system research and development personnel must accurately grasp the working principle of the system.

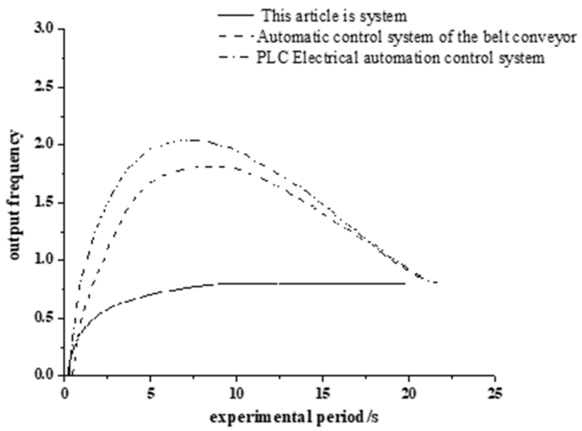


Fig. 5. Unit step PD response of hydraulic turbine system.

Table 2
Unit step performance index of hydraulic turbine system.

Indicators	System	PLC system	Belt conveyor controllable speed change device system
H_p	8.0031	4.36	8.64
H_d	0.6258	0.85	1.3459
Adjust the time	10.05	36.25	16.24
Steady-state adjustment error	0.1677	8.2575	4.1208
The number of overshoot	0.1677	35.6415	18.0125

Declaration of Competing Interest

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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