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SELF-LEARNING ENERGY-SAVING SPEED REGULATION STRATEGY OF BELT CONVEYOR

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Abstract

At present, most belt conveyors operate at a constant speed, which causes very high energy consumption. In order to intelligently adjust the belt speed during the operation of the belt conveyor, reduce energy consumption. This paper presents a self-learning energy-saving speed regulation strategy for belt conveyor. In order to verify the strategy, this paper takes a belt conveyor as an example, and establishes the belt speed-carrying energy consumption model of belt conveyor. Secondly, this strategy combines the piecewise fuzzy PID control method with the self-learning optimisation method. The piecewise fuzzy PID control method is applied to effectively ensure the safety, reliability and accuracy of the belt conveyor speed regulation process, and the self-learning optimisation method is applied to make the belt conveyor automatically modify the carriage-belt speed energy consumption model according to the change of running power. Finally, Simulink toolbox is used to build a simulation model to verify the strategy. The results show that the strategy can effectively adjust the belt speed in the whole life cycle of the belt conveyor, so as to solve the problem of energy consumption caused by the fluctuation of carrying capacity in different running stages. The research results have important guiding significance for realising the energy saving and emission reduction operation of belt conveyor.

Key Words

Energy-saving speed regulation, self-learning optimisation method, fuzzy control, PID control, simulink simulation

1. Introduction

With the increase of social demand for energy, belt conveyor because of its simple structure, good economy, smooth operation and other advantages, is widely used in coal, mining, chemical industry, metallurgy, electric power, building materials, food and other fields [1]. In recent years, a large number of experts and scholars have carried out energy-saving studies in many aspects such as the resistance of belt conveyor idlers [2], parameter design [3], conveyor belt style [4] and speed regulation [5]. Among them, optimising the speed of belt conveyor is a more effective way to save energy. The traditional belt conveyor is usually in accordance with the design of the maximum speed selected continuous operation, and in the actual operation process, the belt conveyor load is real-time change, because the control system cannot automatically adjust the speed of the motor according to the load change, often make the belt conveyor "light load" or "no load" phenomenon, resulting in waste of energy. Therefore, it is necessary to study the speed control system of belt conveyor. He *et al.* [6] proposed an active speed control algorithm for single belt conveyor, by modelling and analysing the belt conveyor system, the simulation showed that an average energy saving of 16.21% per hour can be achieved compared with the traditional given constant speed. Zhou *et al.* [7] introduced fuzzy control on the basis of active speed control algorithm, and set a two-layer fuzzy boundary with the desired value of the material filling rate of the belt to regulate the belt speed by taking the actual value as the input, and verified the feasibility of the fuzzy active speed control strategy through experiment. Tan *et al.* [8] used a polynomial regression fitting algorithm and a small number of sample observations to establish the energy saving of belt conveyor value as input to regulate the belt speed, and the feasibility of the fuzzy active speed control strategy was verified through experiments. In order to accurately measure the coal flow of the conveyor belt to provide the necessary basic data support for the intelligent speed regulation and energy-saving control of the coal mine transportation system, Hou *et al.* proposed a coal flow detection method for conveyor belt based on TOF vision. The experimental results show that the coal flow detection accuracy of this method can reach 97.35%, which can meet the accuracy and real-time requirements of coal mines [9]. Zhang *et al.* proposed a real-time load detection method for belt conveyor based on the detection of area ratio and the

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detection based on laser computer vision technology, which was shown to be more practical through experiments, and at the same time provided a new idea and theoretical basis for the energy-saving control and intelligent development of the conveyor [10]. Ji *et al.* used polynomial regression fitting algorithm and a small number of sample observations to establish an energy saving and consumption reduction model of belt conveyor, and proposed a speed regulation strategy and particle swarm optimisation–proportional–integral–derivative algorithm based on the material flow rate of the belt conveyor with variable speed and energy-saving control, and the simulations showed the energy consumption model and algorithm's simulation shows the effectiveness of the energy consumption model and algorithm. In terms of energy saving and consumption reduction by frequency conversion speed control, many scholars have also made a lot of researches in belt conveyor and other fields [11]–[15]. The above scholars have studied the belt conveyor speed regulation system from the Angle of algorithm and control method, the core of which is to establish the belt speed-carrying capacity energy consumption model to match the corresponding belt speed for different loads to achieve the purpose of energy saving and consumption reduction. However, the current study does not take into account that the energy consumption patterns of belt conveyors throughout their life cycle are constantly changing. With the increase of the service life of the belt conveyor, the problem of inaccurate speed regulation will occur. The self-learning energy-saving speed regulation control strategy studied in this paper can automatically adjust the energy consumption model according to real-time working conditions, so as to realise the accurate match between the speed and the bearing capacity in the whole life cycle of the belt conveyor, which is of great significance for the energy saving and consumption reduction during the operation of the belt conveyor.

1.1 Analysis of Factors Affecting Energy Consumption

According to the "Belt Conveyor Engineering and Technology Standards" (GB 50431-2020) to analyse the energy consumption of the belt conveyor, it can be known that the output power of the motor is shown in (1)

$$P_M = \frac{\mathrm{CLfg}(q_{\mathrm{RO}} + q_{\mathrm{RU}} + 2q_B\cos\delta)}{1000\eta_1}\cdot v + \frac{g(\mathrm{CLf}\cos\delta + H)}{3600}\cdot Q_m \quad (1)$$

Where: C is the additional resistance coefficient; L is the length of the belt conveyor, m; f is the analogue friction coefficient; q_{RO} is the mass per unit length of the rotating part of the upper branch roller, kg$/m$; q_{RU} is the mass per unit length of the rotating part of the lower branch roller, kg$/m$; q_B is the mass per unit length of the conveyor belt, kg$/m$; H is the difference in height between the head and tail of the belt conveyor, m; Q_m is the theoretical mass capacity, t/h; and v is the speed of the belt, m/s.

Where C, L, f, q_{RO}, q_{RU}, q_B, H, Q_m, and v are all factors affecting the motor output power, but in the specific belt conveyor example; the values of C, L, q_{RO}, q_{RU}, q_B, and H are all certain, the main factors affecting the motor output power are the capacity that Q_m and the belt speed that v, where is shown in (2).

$$Q_m = 3.6\mathrm{A}\rho\mathrm{v} \quad (2)$$

Where A is the theoretical cross-sectional area of the conveyor belt bearing material, m^2 and ρ is the bulk material bulk density, t/m^3.

When the cross-sectional area of the material is constant, the belt speed of the belt conveyor and the amount of load is proportional. To increase the cross-sectional area of the material, can be realised in the amount of load under the same circumstances to choose the lowest possible belt speed, reduce the output power of the motor, to achieve the goal of energy saving [16], [17].

1.2 Solving for the Optimum Cross-sectional Area

1) Select the belt speed that v of the belt conveyor, the diameter that D of the rollers, the minimum permissible tension value that $F_{\min}$ of the conveyor belt under the condition of maximum sag, and the dynamic load of the rollers that $P_o{}'$ as the design variables, where is shown in (3).

$$A = (v, D, F_{\min}, P_o{}')^T. \quad (3)$$

2) The design requires that the material cross-sectional area that A on the conveyor belt of the belt conveyor be as large as possible, that is, the objective function which is shown in (4).

$$f(A) = A \to \max. \quad (4)$$

3) *Determine the Constraints:* A belt conveyor as the object of analysis, its main parameters are shown in Table 1:

Table 1
Parameter Table of a Belt Conveyor

Parameter	Numeric Value	Unit
Belt conveyor captain	1500	m
Conveyor belt width	800	mm
First place height difference	30	m
Roller rotation part unit length mass	7.74	kg/m
Idler groove angle	30	Degree
Theoretical mass conveying volume	700	t/h
The bulk density of the bulk material	0.85	t/m^3
Dynamic accumulation angle of the material	20	Degree
Conveyor belt mass per unit length	20	kg/m

a) Belt Sag Limit:

In the "Belt Conveyor Engineering and Technology Standard GB 50431-2020," it is stipulated that the minimum tension should be satisfied with the sag degree as (5):

$$F_{\min} \geq \frac{(A\rho + q_B)a_0 g}{8h_{r.\max}} \tag{5}$$

Where: $F_{\min}$ is the minimum tension of conveyor belt stabilisation, N and $h_{r.\max}$ is the maximum sag of the conveyor belt between two neighbouring roller groups, $h_{r.\max} = 0.01$.

b) Roller load capacity limit, which is shown in (6).

$$P_0' = f_s f_d f_a \; P_0 = \; f_s f_d f_a (A\rho + \; q_B \;) e a_0 g \tag{6}$$

Where: e is the roller load factor, $e = 0.8$; I_m is the belt conveyor per second design mass conveyance, kg/m; f_s is the running coefficient, $f_s = 1.1$; f_d is the impact coefficient, $f_d = 1.0$; and f_a is the working condition coefficient, $f_a = 1.0$.

The bearing capacity of the rollers is determined by the type of belt conveyor rollers, and the calculated load has a guiding role in the selection of the rollers.

c) Limitation of Roller Diameter

The rollers of the belt conveyor have standardised characteristics, and the selection of roller diameter is limited by the width of the conveyor belt, and the optional values of the diameter of the rollers of the rollers in the example are 89mm, 108mm, and 133mm.

d) Conveyor Belt Speed Limitation

The conveyor belt speed is limited by the speed of the rollers which shall not be greater than $600r/min$, which is shown in (7).

$$v \leq 10\pi \text{D}. \tag{7}$$

4) Optimisation model solution for material cross-sectional area that A.

Since the selection of components in the belt conveyor is based on standard specifications, the enumeration method is used to solve the model, which yields (8).

$$\begin{cases} A \leq 0.0651 \\ A \geq \frac{700}{3.6\times 850\times 4.17} \\ [P] \geq (A\cdot 850 + 20)\times 0.8\times 1.2\times 9.81 \\ F_{\min} \geq \frac{(A\cdot 850+20)\times 1.2\times 9.81}{0.08} \end{cases}. \tag{8}$$

Calculation can be obtained in the above constraints, the material cross-sectional area that A of the optimal solution for $0.0651m^2$.

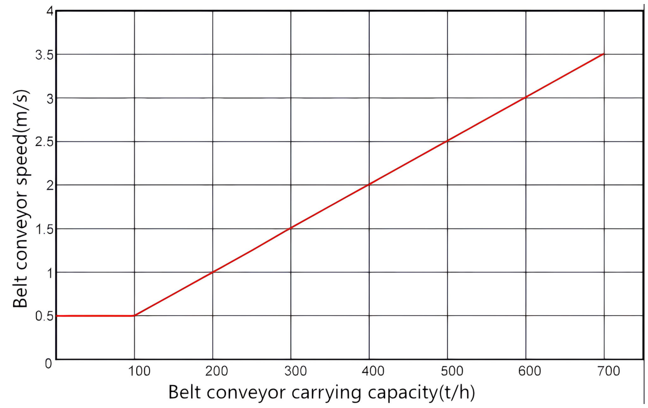

Figure 1. Capacity-belt speed model diagram (before optimisation).

1.3 Modelling of Energy Consumption of Carrying Capacity-belt Speed

Based on the optimal cross-sectional area of the material obtained by solving the establishment of the belt conveyor capacity–belt speed energy consumption model, in order to avoid the conveyor no-load condition of frequent start and stop on the power grid to form a large impact, the proposed minimum belt speed is $0.5m/s$, to get the initial energy consumption model of the capacity–belt speed shown in Fig. 1.

At the same time in the operation of the belt conveyor, in order to avoid the belt conveyor due to the capacity of a small range of fluctuations in the need for uninterrupted adjustment of the belt speed, so the belt speed for the segmented specification, that is, for each interval section of the capacity to set a fixed value of the belt speed, after the amendment to obtain the capacity-belt speed energy consumption model shown in Fig. 2.

Taking the optimised capacity-belt speed model as the basis of speed control, the segmented fuzzy PID speed control is proposed by combining the PID control and fuzzy control to realise the precise control of belt speed. In order to cope with the energy consumption problem caused by the change of running resistance in the whole life cycle of the belt conveyor, a self-learning optimisation method is proposed for the capacity-belt speed model, and at the end of the speed regulation cycle, by comparing the value of the output power of the frequency converter returned by the power acquisition module and the size of the value of the power in the capacity-belt model, if the value of the output power of the frequency converter is in the range of the value of the energy consumption model, it is possible to achieve the precise control of the belt speed. If the value of the output power of the frequency converter is within the range of the power value in the energy consumption model, it means that the operation state is good at this time and there is no need to optimise the energy consumption model; if the value of the power exceeds the range of the power value in the energy consumption model, then the corresponding optimisation action is executed. Figure 3 shows the overall block diagram of the self-learning energy-saving speed control strategy for belt conveyor.

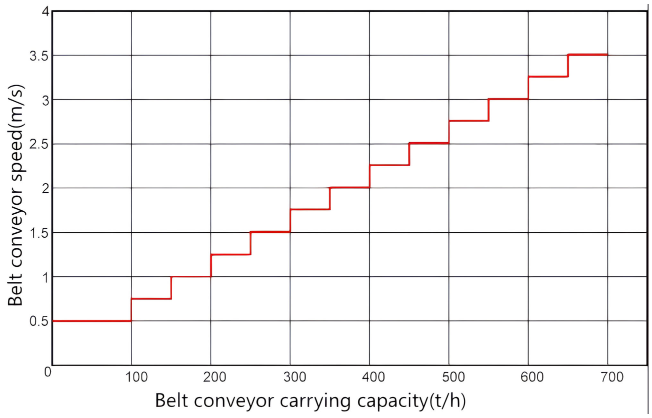

Figure 2. Capacity-belt model diagram (optimised).

2. Self-learning Speed Control System Design

2.1 Segmented Control System Design

When designing the belt conveyor control system based on the aforementioned capacity-belt speed energy consumption model, there are three main control objectives; the speed regulation process is safe and reliable; it has a small overshoot; and it has a high control accuracy. In modern control technology, fuzzy control and PID control have their own fields of application [18]–[20], fuzzy algorithm and PID algorithm are as follows:

1) Fuzzy Algorithm:

S1: First import the fuzzy controller library.

S2: Define the input variables that e (speed deviation), ec (rate of change of speed deviation) and output variable that p (control quantity) and specify their fuzzy domains as$[-6, 6]$.

S3: Classify each fuzzy variable into fuzzy sets (NB (negative large), NM (attached medium), NS (attached small), ZO (zero), PS (positive small), PM (positive medium), and PB (positive large)) through the trimf function and use the trimf function as the affiliation function for each variable.

S4: Map the fuzzy sets of input variables to the fuzzy sets of output variables by fuzzy rules.

S5: Pass the fuzzy rules as parameters to the control system.

S6: Judge the speed deviation value, satisfy the fuzzy control requirements, carry out fuzzy control, otherwise, carry out other control.

S7: Calculate the output according to the fuzzy rules for the inputs that satisfy the fuzzy control and observe the control results.

2) PID Algorithm:

S1: Set the target value, that is the speed deviation value. Represents the error that we want the system to eliminate, and sets the initial position to represent the current position of the system.

S2: Set the sampling time that $T_s = 0.1s$ and PID control coefficient, and set the scale factor ($K_p = 0.9$), integration factor ($K_i = 0.001$) and differential coefficient ($K_d = 3.1$), which are used to control the weights of error, error accumulation, and error variation.

S3: Initialize the error variable, the last error variable (last-error), and the integral term (integral) to 0, which is used to record the current error, the last error, and the error accumulation.

S4: Control continuously with a while loop until the system reaches the target value.

S5: At the beginning of each loop, get the value of the current position and update it to the position variable.

S6: Calculate the current error and the change in error, and also divide the change in error by the sampling time T_s to obtain the differential of the continuous system.

S7: Multiply the scale coefficient by the error, the integration coefficient multiplied by the error accumulation and the differential coefficient by the error change, and calculate the control quantity, which represents the correction amount output of the controller.

S8: Update the integration term by multiplying the accumulated error by the sampling time to handle the persistent bias.

S9: Assigns the current error to the previous error for the calculation of the next loop.

S10: Output the current position and control quantity, debug and observe the control results.

Combining the advantages and disadvantages of PID control and fuzzy control listed in Table 2, a segmented control strategy based on PID control and fuzzy control is proposed. It can realise the safety, reliability and accuracy of the speed control action of the belt conveyor under the demand of different belt speeds, and its flow block diagram is shown in Fig. 4.

In this strategy, the core part is the comparator logic in the flow block diagram, and by obtaining the deviation value of the real-time belt speed of the belt conveyor and the reference belt speed derived from the real-time capacity of the belt conveyor in accordance with the energy consumption model of the capacity-belt speed, and by selecting different control modes according to the magnitude of the deviation value, the control logic is:

(1) For the significant characteristics of belt conveyor with large delay and hysteresis, considering that fuzzy control does not need accurate mathematical model, it is taken as the main control method;

(2) In fuzzy control, it is assumed that when the domain of deviation thesis is $n = 6$,When the deviation is less than 8.33% of the maximum value of a of the deviation range, the fuzzy control cannot eliminate the steady state error. In order to cope with the above control failures, PID control is used up to 8.33% of the deviation range that a;

(3) By analysing the discrete form of PID control, which is shown in (9).

$$u(k) = K_P e(k) + K_i \sum_{j=0}^{k} e(k) + K_d[(e(k) - e(k-1))] \quad (9)$$

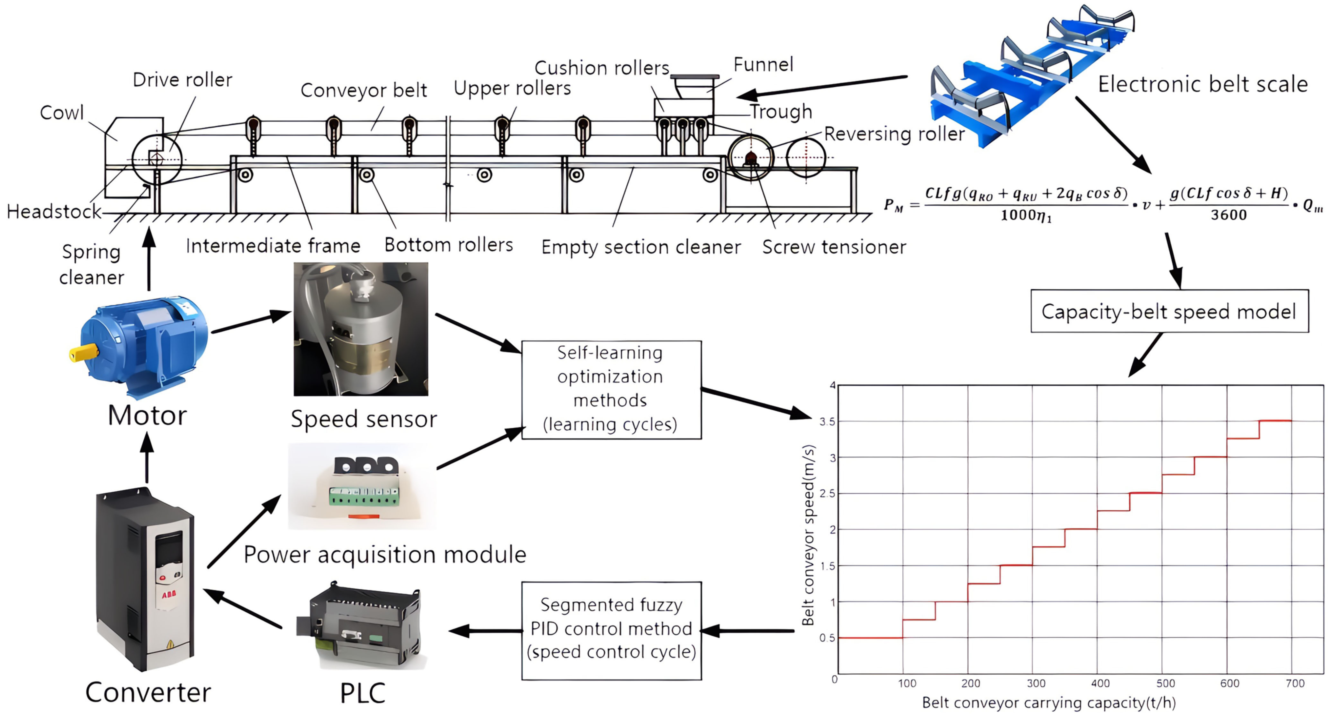

Figure 3. Schematic diagram of self-learning energy-saving speed control strategy framework.

Table 2
Comparison of Advantages and Disadvantages of PID Control and Fuzzy Control

	Merit	Shortcoming
PID control	The principle is relatively simple	Limitations of parameters
	Good system stability	Parameters are mutually restricted
	Easy to adjust precisely	Limitations of usage scenarios
Fuzzy controls	You don't need to know the model of the system	Low control accuracy
	Wide range of usage scenarios	Low system stability

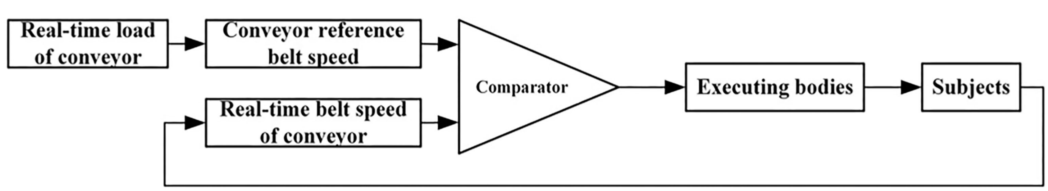

Figure 4. Segmented energy-saving control strategy flow block diagram.

Where: K_p is the proportionality coefficient; K_i is the integral coefficient; and K_d is the differential coefficient.

It can be found that the control quantity generated by the proportional link is only related to the deviation of the kth; the control quantity generated by the differential link is related to the deviation of the kth and the (K-1)th; the control quantity generated by the integral link is related to the sum of the deviation of the previous kth, which may cause overshooting, therefore, the PD control with the removal of the integral link is introduced in the PID control link to avoid overshooting. The key lies in choosing the appropriate deviation value for switching between PID and PD control. Through many simulation tests, the deviation value of 0.28 is a reasonable switching value. Figure 5 shows the block diagram of the segmented control strategy.

2.2 Self-learning Energy-saving Speed Control Strategy

As the operating life of the belt conveyor increases, the rotating parts transition from the break-in period to the wear stage, and the load-belt speed energy consumption model calculated based on the intrinsic parameters cannot accurately adapt to the increase in energy consumption

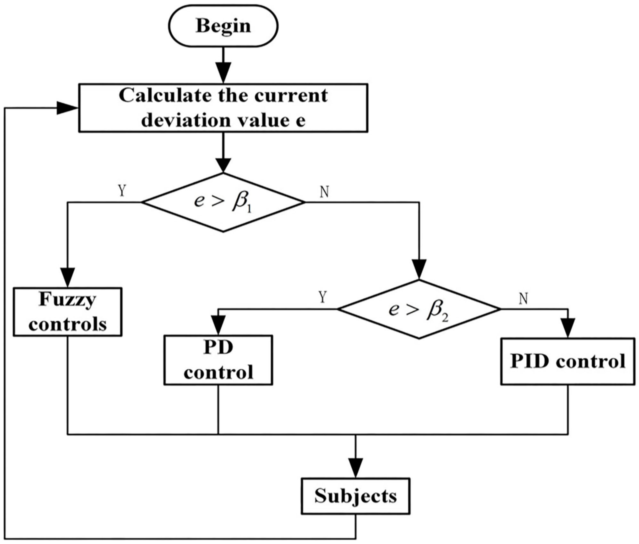

Figure 5. Block diagram of the segmented control strategy.

of the belt conveyor with the increase in the operating life of the belt conveyor [20], [21], and in this regard, a self-learning energy-saving speed control strategy is proposed, which collects the load, belt speed and inverter output power during the operation of the belt conveyor and continuously corrects the initial load-belt speed energy consumption model according to the self-learning algorithm. By collecting the load, belt speed and inverter output power during the operation of the belt conveyor, the initial load-belt speed energy consumption model is continuously corrected according to the self-learning algorithm, so that the load-belt speed energy consumption model of the belt conveyor can maximally adapt to the change of the conveyor's working conditions, and the flow is shown in Fig. 6.

Based on the above requirements, the logic of the self-learning energy-saving speed control strategy for belt conveyor is designed as follows.

(1) The real-time carrying capacity of the belt conveyor is obtained by the belt scale, and the real-time output power P of the inverter is obtained by the inverter power detection module.
(2) The real-time carrying capacity is selected to correspond to the carrying capacity interval segment in the carriage-speed energy consumption model, and the lower power limit $P_{\min}$ and upper power limit $P_{\max}$ of the carrying capacity interval segment are obtained.
(3) According to the relationship between P, $P_{\min}$ and $P_{\max}$, the carriage-belt speed energy consumption model is modified in real time (see Table 3).

Table 3
Self-learning Energy-saving Speed Regulation Strategies

	v	$P_{\min}$	$P_{\max}$
$P < P_{\min}$	$v_i - \frac{(v_i - v_{i-1})(P_{i,min} - P)}{(P_{i,min} - P_{i-1,min})}$	P	$P_{\max}$
$P_{\min} < P < P_{\max}$	v	$P_{\min}$	$P_{\max}$
$P_{\max} < P$	$\frac{(P - P_{i,max})(v_{i+1} - v_i)}{(P_{i+1,max} - P_{i,max})} + v_i$	$P_{\min}$	P

Table 4
Belt Conveyor Drive Device Selection Table

Device Name	Main Parameters
Motor	Model:M2BAX, Number of pole pairs:6P, rotate speed:1500r/min, Rated power:250kw, Rated voltage:380v
Gearbox	Reduction ratio:1:20, Rated power:296kw
Drive the drum	Diameter:800mm
Frequency converters	Model:ACS880-01-430A-3

3. Simulink Simulation Analysis

3.1 Simulink Simulation Analysis Process

The drive selection is completed for the aforementioned belt conveyor example as shown in Table 4:

The Simulink toolbox is a software package for modelling, simulation and analysis of dynamic systems in MATLAB. Simulink is used to validate the self-learning energy-saving speed control strategy for belt conveyor simulation under different capacities.

The control rules are established for the fuzzy control toolbox in which the central idea of the design is:

a) When the carrying capacity increases, the real-time belt speed is smaller than the reference belt speed and the acceleration is negative, the control volume that P should be positive;
b) When the carrying capacity increases, the real-time belt speed is less than the reference belt speed, and the acceleration is positive, the control quantity P should be centered.
c) When the carrying capacity decreases, the real-time belt speed is greater than the reference belt speed, and the acceleration is negative, the control quantity P should be centered.
d) When the carrying capacity decreases, the real-time belt speed is greater than the reference belt speed, and the acceleration is positive, and the control quantity P should be negatively large.

In the above control rules, to ensure the stability of the belt conveyor as the most important control objective, when the speed deviation is small, the control volume should pay attention to prevent overshooting; when the speed deviation is large, to eliminate the error as soon as possible. Summarize the above control rules and supplement the control rules to get Table 5.

In summary, the simulation model shown in Fig. 7 is established, in which the driving part of the belt conveyor realizes the simulation from the frequency converter to the actual running speed of the conveyor belt through the transfer function, which is shown in (10)–(13).

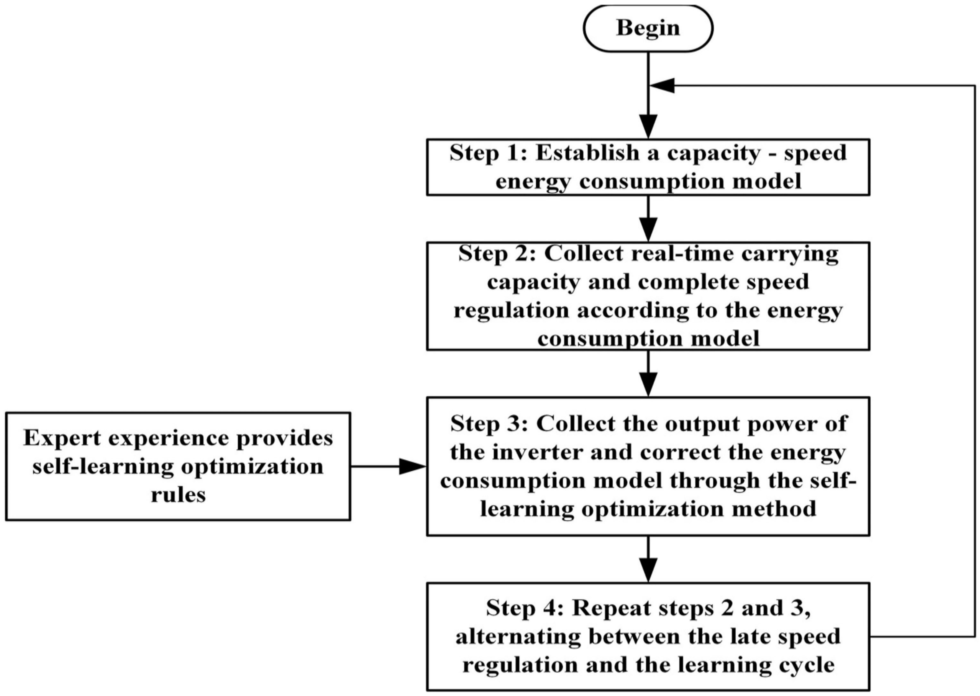

Figure 6. Complete flowchart of self-learning energy-saving speed regulation strategy.

Table 5
Fuzzy Rule

P		E						
		NB	NM	NS	ZO	PS	PM	PB
EC	NB	ZO	ZO	PS	PM	PM	PB	PB
	NM	NS	ZO	ZO	PS	PM	PB	PB
	NS	NM	NS	ZO	PS	PS	PM	PB
	ZO	NM	NM	NS	ZO	PS	PM	PM
	PS	NB	NM	NS	NS	ZO	PS	PM
	PM	NB	NB	NM	NS	ZO	ZO	PS
	PB	NB	NB	NM	NM	NS	ZO	ZO

Motor:

$$G_1(s) = \frac{30}{1+0.5s}. \tag{10}$$

Gearbox:

$$G_2(s) = \frac{1}{20s}. \tag{11}$$

Frequency converter:

$$G_3(s) = \frac{0.1216}{1+5s}. \tag{12}$$

Conveyor belt:

$$G_4(s) = e^{-\tau e}. \tag{13}$$

The transfer function from the frequency converter input frequency to the conveyor belt speed is obtained by collation, which is shown in (14):

$$G(s) = \frac{0.3947}{5s^3+11s^2+2s}e^{-\tau s} \tag{14}$$

3.2 Simulink Simulation Results and Analysis

The simulation verification for the learning energy-saving speed control strategy is carried out according to the three working conditions listed in Table 3.

Working Condition 1: The belt conveyor is in the stable operation stage, that is, there is no severe wear or slack phenomenon of the rotating parts. Given the simulation model of the self-learning optimisation method and the random material flow of the control group, the simulation results output by the scope module are shown in Fig. 8.

The black line in Fig. 8 indicates that the PLC module obtains the reference belt speed of the belt conveyor by reading the material flow returned by the electronic belt scale; the red line represents the belt speed of the speed regulating control system with self-learning optimisation method; the green line represents the belt speed of the speed regulating control system without self-learning. It can be found from the figure that the red line and the green line completely coincide and change with the change of the black line. It can be concluded that in the stable stage of the belt conveyor, the self-learning energy-saving speed regulation control strategy is consistent with the control group's adjustment of the belt speed, which is in line with the expected effect.

Condition two: The belt conveyor enters the stage of severe wear from stable operation, that is, excessive wear of rotating parts. Given the simulation model of self-learning optimisation method and the same random material flow

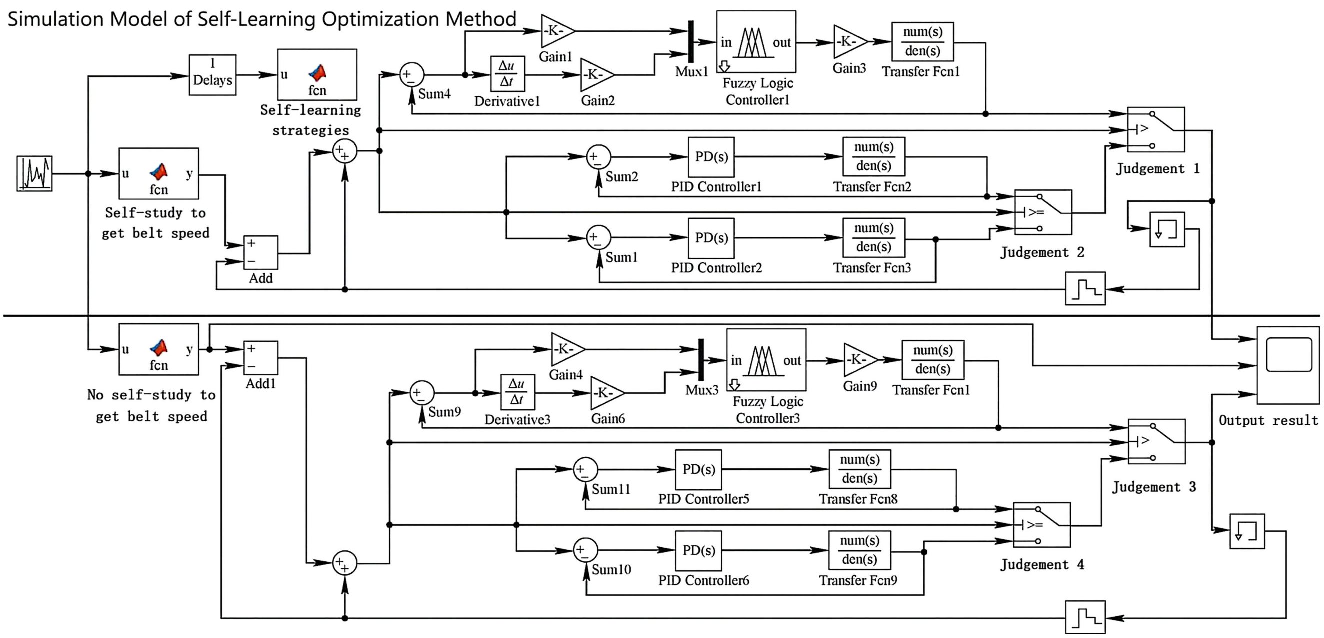

Figure 7. Self-learning energy-saving speed regulation simulation comparison verification diagram.

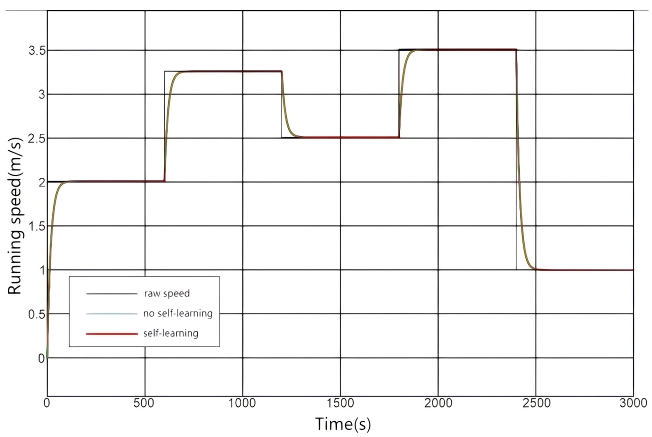

Figure 8. When $P_{\min} < P < P_{\max}$, do not perform speed correction.

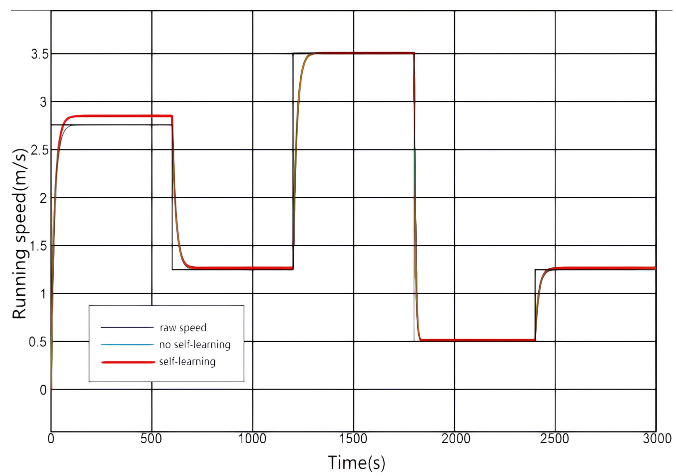

Figure 9. When $P_{\max} < P$, perform a band speed increase correction.

as the control group, the simulation results output by scope module are shown in Fig. 9.

As can be seen from Fig. 9, in the first speed regulation interval, the red line indicates that the belt speed of the controlled object with the self-learning optimisation method is higher than that of the control group. That is, when the belt conveyor enters the severe wear stage from the stable operation stage, the self-learning optimisation method has an increased correction on the belt speed in the energy consumption model, which is in line with the expected effect.

Condition three: The belt conveyor in the operation process from the break-in period to the stable operation stage, that is, the output power of the frequency converter is $P < P_{\min}$, set with self-learning energy-saving speed control and no self-learning energy-saving speed control comparison simulation analysis, the results are shown in Fig. 10.

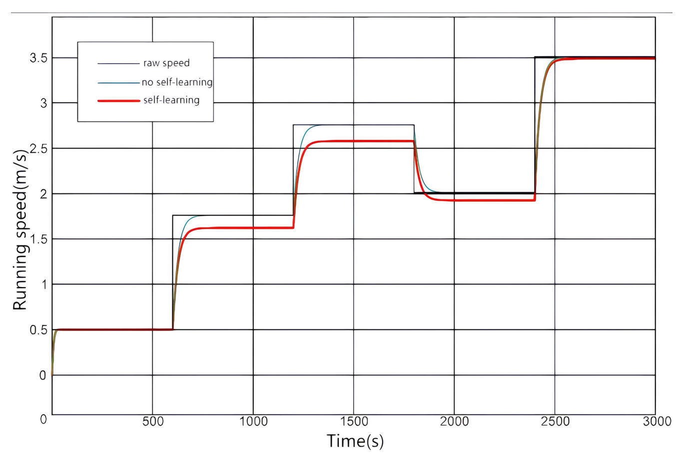

Figure 10. When $P < P_{\min}$, perform a band speed reduction correction.

As can be seen from Fig. 10, in the second, third and fourth speed regulation intervals, the red line indicates that the belt speed of the controlled object with the self-learning optimisation method is lower than that of the control group, that is, when the belt conveyor enters the stable operation stage from the running-in period, the self-learning optimisation method has reduced the belt speed in the energy consumption model, which is in line with the expected effect.

Through the simulation analysis of the above three working conditions, we can see: The energy-saving speed regulation control strategy of belt conveyor based on self-learning proposed in this paper can modify the belt speed-carrying capacity energy consumption model of belt conveyor under different working conditions by self-learning optimisation method, and take the modified belt speed-carrying capacity energy consumption model as the basis for speed regulation control, so as to make timely and accurate speed regulation actions for the belt speed of belt conveyor according to the real-time load.

4. Conclusion

Aiming at the energy consumption problem of belt conveyor running at constant speed, this paper combines the piecewise fuzzy PID algorithm with self-learning optimisation method, and puts forward an energy-saving speed regulation strategy based on self-learning. Simulation results show that this strategy can dynamically modify the belt-speed-carrying capacity energy consumption model in real time, and based on the real-time modified belt-speed-carrying capacity energy consumption model, the belt conveyor can adjust its speed timely and accurately according to the real-time carrying capacity in the whole life cycle. However, because the speed control strategy designed in this paper adopts a fixed speed control period value, it cannot accurately match the speed control time required for different speed deviations to achieve maximum energy saving. In the future, more advanced sensing technology and automatic control systems will be introduced to achieve intelligent adjustment and optimisation of conveyor speed, pay attention to the application of energy-saving technology, improve energy efficiency, and promote the belt conveyor industry to a higher level of development through the design of low noise and low vibration belt conveyor.

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