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Speed Control and Optimization of Variable Speed Diesel Generator Set

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Abstract: The fuel consumption rate of a diesel engine is closely related to its operating speed. In order to minimize the fuel consumption rate of the diesel engine, this paper studies the optimal operating speed of the diesel generator set, and designs the optimal operating speed curve of the diesel generator based on the actual situation. Aiming at the phenomenon that the load changes at any time in the actual working condition of the diesel generator set, this paper designs a fuzzy adaptive PID control algorithm for the diesel engine governor and realizes algorithm optimization. Using MATLAB platform simulation analysis, it is verified that the fuzzy adaptive PID controller after algorithm optimization has better dynamic response and stability performance in diesel generator system.

Keywords: algorithm optimization; fuzzy adaptive PID; MATLAB; optimal operating speed curve

1 INTRODUCTION

The introduction of variable-speed power generation technology into variable-speed diesel generator sets has become a new research direction in the field of ships [1]. The biggest advantage of variable speed power generation lies in its good fuel economy, and the fuel consumption rate of a diesel engine is closely related to its operating speed [2]. In order to reduce the fuel consumption rate of the diesel engine to the greatest extent, it is extremely important to study the optimal operating speed of the diesel generator set. Modern diesel engines are equipped with governors, and the quality of the governor's control algorithm directly affects the governor's control of the speed [3], so the research on the excellent control algorithm of the diesel engine governor is also imminent.

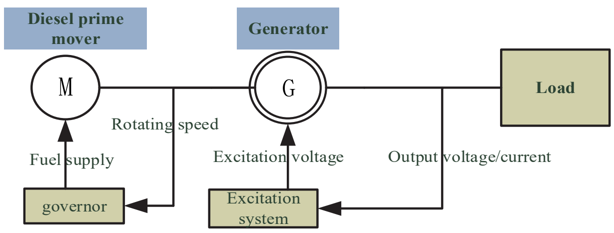

Figure 1 System structure diagram of variable speed diesel generator set

The diesel engine model used in this article has a rated speed of 700 r/min, a minimum full load speed of 300 r/min, and a rated power of 64 kW. The generator adopts a brushless doubly fed generator with the following parameters: power 64 kW; rated voltage 380 V; speed 300 rpm ~ 700 rpm; P_p = 4; P_c = 2; J = 0.03 kg/m^2; R_p = 0.075 Ω; R_c = 0.11 Ω; R_r = 0.931 Ω; L_{sp} = 0.04205 H; L_{sc} = 0.16188 H; L_r = 1.0775 H; M_{pr} = 0.11745 H; M_{cr} = 0.33585 H. Where, P is the pole pair, J is the Moment of inertia, r is the resistance, L is the inductance, M_{pr} is the mutual inductance between the power winding at the stator side and the rotor winding, M_{cr} is the mutual inductance between the control winding at the stator side and the rotor winding, where the subscripts (p, c, r) are the power winding at the stator side, the control winding at the stator side, and the rotor winding, respectively.

In order to ensure the optimal control requirements for the operation of the diesel engine system, in recent years, after continuous research by people in the industry, electronic control technology for diesel engines, also known as electronic control technology, has been proposed [4]. The current research on diesel electronic control technology mainly focuses on three aspects: 1) Research on various components of the electronic control system [5-10]. The manufacturing and processing of sensors with high reliability, high sensitivity, and excellent electromagnetic anti-interference ability and high-precision, high-response speed actuators has always been the focus of research, and it is also the future development trends of electronic control system component. 2) Research on the mathematical model of the electronic control system [11-18]. The current electronic governor generally adopts negative feedback regulation to control the diesel engine speed, so a more accurate electronic control system and a more suitable diesel engine mathematical model will play a key role in the control system. 3) Research on control algorithm and theory. The controller (ECU) is the brain of the electronic governor. The signal received by the sensor is processed by the controller to obtain the voltage signal to drive the actuator. Therefore, the quality of the control algorithm directly determines the quality of the control of the electronic governor. Internationally, outstanding achievements have been made in the process of researching control algorithms [19-27], such as: PID control algorithm, fuzzy control algorithm, fuzzy PID control algorithm, current double closed-loop control algorithm, RBF neural network control algorithm, etc. However, with the improvement of control accuracy requirements, these control algorithms are no longer able to meet existing requirements well. Based on previous research results, while designing the optimal operating speed of variable speed diesel generator set, this paper conducts more in-depth research on the controller algorithm of variable speed diesel generator set, and finally makes this research Diesel generator system obtain better performance through algorithm optimization.

2 RESEARCH ON OPTIMUM OPERATING SPEED OF VARIABLE SPEED DIESEL UNITS

For the study of the optimal operating speed of variable-speed diesel generator sets, the focus is on the power output characteristics of the diesel engine, while the research on the diesel engine body model is ignored.

Therefore, in the modeling process, it is not necessary to consider the diesel engine supercharging, intake and exhaust, and combustion process models, but to use the simplified average model [28]. The power output characteristic of a diesel engine is a physical quantity related to the rotational speed and the circulating fuel supply, so it is only necessary to build a mathematical model related to the output torque of the diesel engine, the diesel engine speed, and the circulating fuel supply of a single cylinder.

Yang Feng and other scholars provided test data and fitting curves [29]. The significance of these curves and data means that a group of single cylinder cycle injection quantity and diesel engine output torque values will be measured when the speed of the diesel engine is kept constant at a certain time. When Ceteris paribus, the diesel engine speed will be changed at another time so that a group of data about single cylinder cycle injection quantity and diesel engine output torque will be measured. By fitting these experimental data according to a certain pattern, a fitting curve can be obtained. According to the fitting curve, it can be obtained that the output torque of the diesel engine and the fuel injection rate of a single cylinder cycle of the diesel engine are approximately a quadratic function when the speed is kept constant. Since the four-stroke diesel engine is used as the research object in this paper, the number of cylinders is 6. When the speed remains constant, the output torque of the diesel engine can be expressed as a linear expression related to the fuel injection quantity of a single cylinder cycle.

$$T = 6\left(ad + b\right) \tag{1}$$

In the formula, a and b are coefficients; d is the cycle fuel injection quantity of a single cylinder; T is the output torque of the diesel engine.

When the rotational speed changes, it can be found that the coefficients a and b have a linear function relationship with the diesel engine rotational speed respectively.

$$\begin{cases} a(\omega) = 0.00527\omega + 0.80702 \\ b(\omega) = -0.353\omega - 12.76766 \end{cases} \tag{2}$$

where ω is the angular velocity of the diesel engine.

Therefore, under a certain working condition at a certain moment, the diesel engine output torque T has the relationship with the diesel engine angular velocity ω and the single-cylinder circulating fuel supply d as in Eq. (3).

$$T = 6\left(\left(a_1\omega + a_2\right)d + b_1\omega + b_2\right) \tag{3}$$

And because the fuel consumption per hour m_f/ g/h of the variable speed diesel generator set is:

$$m_f = 6\frac{3600}{1000 \times 4\pi} d\omega = \frac{5.4}{\pi} d\omega \tag{4}$$

Arrange Eq. (3) into an expression about angular velocity and put it into Eq. (4):

$$m_f = \frac{5.4}{\pi}\left[C_1\omega(a) + C_2 + \frac{P_d / 6 + C_3}{\omega(a)}\right] \tag{5}$$

In the formula, P_d is the output power of the diesel engine;

$C_1 = \frac{-b_1}{a_1^2}$; $C_2 = \frac{2a_2b_1}{a_1^2} - \frac{b_2}{a_1}$; $C_3 = -\frac{b_1a_2^2}{a_1^2} + \frac{b_2a_2}{a_1}$; $\omega(a) = a_1\omega + a_2$.

In order to obtain the best operating speed of the diesel engine, the actual purpose is to find the best speed value when the fuel consumption m_f per hour of the variable speed diesel generator set is the smallest when the output power P_d of the diesel engine is constant, that is:

$$m_{f\min} = \min\left\{m_f\left(\omega(a), P_d\right)\right\} \tag{6}$$

In Eq. (5), C_1, C_3 and $\omega(a)$ are always greater than or equal to 0, so the optimal angular speed point of the variable speed diesel generator set can be calculated according to Eq. (7).

$$\frac{\partial m_f}{\partial\omega(a)} = C_1 - \frac{P_d / 6 + C_3}{\omega(a)^2} = 0 \tag{7}$$

When $\omega(a) = \sqrt{\left(P_d / 6 + C_3\right) / C_1}$, m_f has a minimum value, so the optimal angular velocity ω_{opt} of the diesel engine can be obtained as:

$$\omega_{opt} = \frac{\omega(a) - a_2}{a_1} \tag{8}$$

In a variable speed diesel engine power generation system, the capacity of the frequency converter is sometimes equal to or even greater than that of the generator. Therefore, when considering the system loss, the loss of the inverter and the generator must be taken into account. Here it is set to a constant value (accounting for $(1 - \eta)$ of the total power, $\eta = 0.85$), then the load power P_1 is:

$$P_1 = \eta P_d \tag{9}$$

Then use P_1 to represent the optimal operating speed n_{opt} of the diesel engine as:

$$n_{opt} = \frac{30}{\pi}\frac{\sqrt{\left(P_1 / 6\eta + C_3\right) / C_1} - a_2}{a_1} \tag{10}$$

The rated speed of the diesel engine model selected in this paper is 700 rpm, and the minimum operating speed is 300 rpm. Therefore, in the actual operation of the diesel generator, the upper and lower limits of the speed value must be set. Fig. 2 is the speed curve obtained according to the optimal speed operation calculation formula.

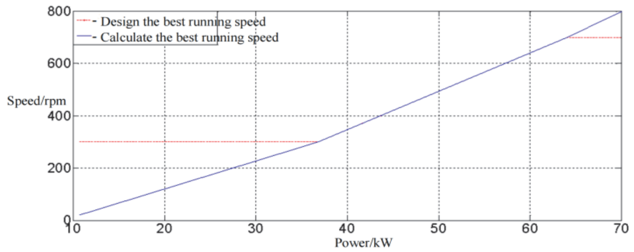

Figure 2 Optimum operating speed curve of variable speed diesel generator set

3 RESEARCH ON CONTROL ALGORITHM OF DIESEL ENGINE GOVERNOR

The speed control of variable speed diesel generator set is realized by the energy-saving control unit, and the speed control strategy is the core of the energy-saving control unit. The energy-saving control unit collects real-time load power from the frequency converter, sets the diesel engine speed according to the designed speed control strategy, and adjusts the diesel engine speed to the set speed, thereby achieving the goal of variable speed and energy-saving.

The design of speed control strategy of variable speed diesel generator set depends on the optimal energy efficiency curve and unit load of the variable speed diesel generator set. In its speed control strategy, the variable speed diesel generator set operates at a limited speed point. For different unit load conditions, the selection of operating speed point will have an impact on the overall fuel economy of the unit. Therefore, customized design is required according to the actual load conditions.

3.1 Research on Fuzzy Adaptive PID Control Algorithm

Fuzzy adaptive PID control is a new control method [30]. The principle of fuzzy adaptive PID control is to realize online adjustment of PID control parameters in fuzzy control, rather than directly acting on the basis of the control principle of the controlled object. The deviation e and the deviation change rate e_c between the system setting and the output of the controlled object are used as the input of the fuzzy controller, so that when the system is working, since e and e_c are continuously given input to the fuzzy controller in real time, the controller will continuously realize the real-time optimization processing of the PID controller parameter K_c (The subscript c represents p, i, d respectively), so that the output of the system will be more accurate.

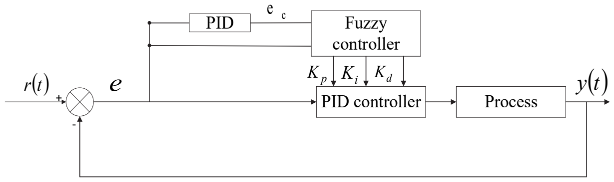

Figure 3 Schematic diagram of fuzzy PID control of variable speed diesel generator set

The design basis of fuzzy adaptive PID controller is actually the research and design of fuzzy controller. When establishing a fuzzy controller, three problems must be solved during its design process, namely fuzzy quantification of input and output, construction of fuzzy control rules and implementation of fuzzy decision-making.

3.1.1 Perform Fuzzy Quantization Processing on Input and Output

First, determine the domain of quantification and quantification factor of the input quantity. The basic domain of the definition variable x is [x_1, x_2], and the quantitative domain X = {−6, −5, −4, −3, −2, −1, 0, 1, 2, 3, 4, 5, 6}, by establishing the fuzzy model of the input quantity in Eq. (11), and the corresponding fuzzy subset {NB, NM, NS, ZO, PS, PM, PB} with the quantization domain X of x, {NB, NM , NS, ZO, PS, PM, PB} represent {negative large, negative medium, negative small, zero, positive small, positive medium, positive large} in turn, so as to realize the fuzzification of the input quantity.

$$K_1 = \frac{12\left(x - \frac{x_1 + x_2}{2}\right)}{x_2 - x_1} \tag{11}$$

Second, determine the quantitative domain and quantitative factor of the output. The method of defining the fuzzy subset {ZO, PS, PM, PB} and the quantitative discourse Y is the same as the definition method of the input quantity. By establishing the fuzzy model of the output quantity in Eq. (12), {ZO, PS, PM, PB} represent successively {zero, small, medium, large}, so as to realize the fuzzy output.

$$K_2 = \frac{y_2 - y_1}{6} \tag{12}$$

3.1.2 Construct Fuzzy Control Rules

The basic control requirements of general control systems are sensitive dynamic response and good steady-state characteristics. In the traditional PID controller, the dynamic response speed and adjustment accuracy of the system are determined by the proportional coefficient K_p. In fuzzy adaptive PID controller, the input |e| of fuzzy control is proportional to K_p. In the early stage of adjustment, increase K_p to improve the dynamic response speed of the system. In the mid-term of adjustment, K_p should be reduced correspondingly considering the adjustment accuracy of the system. In the later stage of adjustment, K_p must be further reduced; at this time, the response speed of the system is no longer the focus of control, but the stability of the system should be paid attention to to avoid system oscillation and overshoot.

Table 1 Fuzzy control rule list of K_p

e_c\\e	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	PS	ZO
NM	PB	PB	PM	PM	PS	ZO	ZO
NS	PM	PM	PM	PS	ZO	PS	PM
ZO	PM	PM	PS	ZO	PS	PM	PM
PS	PS	PS	ZO	PS	PS	PM	PM
PM	PS	ZO	PS	PM	PM	PM	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

In the conventional PID controller, it is difficult to realize the dynamic response speed of the system and increase the adjustment accuracy of the system stability only by K_p alone, and because the proportional control can only control the current system, but cannot realize the memory of the system Function, that is, there is a static error, so the integral coefficient K_i must be introduced to eliminate the static error. The value of K_i is roughly proportional to its ability to eliminate static errors, but because the input $|e|$ of fuzzy control is also proportional to the integral, that is, the larger $|e|$ overshoot and stability domain oscillations of the control system will increase. Therefore, in fuzzy control, K_i should be adjusted in real time. In the early stage of adjustment, reduce K_i to avoid excessive system overshoot; and in the middle stage of adjustment, relatively increase K_i to comprehensively consider the stability characteristics of the system. The deviation $|e|$ of the system is small and no longer has a great impact on the integral. Considering the adjustment accuracy of the system, increase K_i again to reduce the steady-state error of the system.

Table 2 Fuzzy control rule list of K_i

$e_c \backslash e$	NB	NM	NS	ZO	PS	PB
NB	PB	PB	PM	PM	PM	ZO
NM	PB	PB	PM	PM	PS	ZO
NS	PB	PM	PS	PS	ZO	PS
ZO	PM	PM	PS	ZO	PS	PM
PS	PM	PS	ZO	PS	PS	PM
PM	ZO	ZO	PS	PM	PM	PB
PB	ZO	ZO	PS	PM	PB	PB

In the conventional PID controller, the differential adjustment K_d is rarely used, because the function of K_d is only to generate a predictive value for the leading action control system to improve the dynamic characteristics of the system. In fuzzy control, the input variable $|e_c|$ has a direct proportional relationship with the differential coefficient K_d, so, in fuzzy control, K_d should be adjusted in real time. In the initial stage of adjustment, considering the dynamic response of the system at this time, K_d should be increased to prevent the system from overshooting too much. In the middle stage of adjustment, K_d is relatively reduced to comprehensively consider the stability characteristics of the system. In the later stage of adjustment, the input deviation change rate $|e_c|$ of the system is small at this time, and no longer has a great impact on the differential. At this time, the steady-state characteristics of the system should be considered, and K_d should be reduced again to reduce the steady-state error of the system.

Table 3 Fuzzy control rule list of K_d

$e_c \backslash e$	NB	NM	NS	ZO	PS	PM	PB
NB	PS	PS	PB	ZO	ZO	PB	PB
NM	PS	PS	PB	PS	ZO	PS	PM
NS	ZO	PS	PM	PS	ZO	PS	PM
ZO	ZO	PS	PS	PS	ZO	PS	PM
PS	ZO	ZO	ZO	PS	ZO	PS	PS
PM	PB	PS	PS	PS	ZO	PS	PS
PB	PB	PM	PM	ZO	ZO	PB	PB

The weighted average algorithm is used to realize fuzzy judgment and defuzzification for fuzzy control.

3.2 Fuzzy Adaptive PID Control Optimization Algorithm

In the variable-speed diesel generator system, according to the operating principle of the optimal speed of the diesel generator set, the speed of the diesel engine will change according to the change of the load and finally run at an optimal value. During the actual system operation, the load is a quantity that changes with time, so the speed will also be a quantity that changes with the load. It can be seen from the previous analysis that whether it is a fuzzy adaptive PID controller or a conventional PID controller, the adjustment of the speed is only based on the deviation of the speed through differential action to generate a predicted value for the leading action control system to adjust the fuel supply of the diesel engine so as to achieve the effect of improving the dynamic characteristics of the system. In fact, there is a time lag when this method is used to improve the dynamic characteristics of the system, because the first change of the system is the load rather than the speed, so the dynamic characteristics of the adjustment system will be improved in some control systems by estimating the predicted value through the speed deviation. It is difficult to be realized in a system with high precision requirements. Not only that, since the frequency of the generator is related to the speed regulation characteristics of the diesel engine, in order to improve the dynamic characteristics of the diesel generator set and the output frequency characteristics of the generator, the load feedforward-speed feedback adaptive-fuzzy optimization control algorithm is used to improve the system. Dynamic features appear more timely. The advantage of feed-forward control is that when the load changes, its working time should be ahead of the speed change, so the system will have faster dynamic response and adjustment accuracy.

In the fuzzy adaptive PID controller mentioned above, the diesel engine governor controls the oil supply mechanism according to the speed feedback difference to adjust the speed. The load feedforward-speed feedback will add a load feedback on the premise of the original speed feedback. Since the response speed of the load feedback will be much higher than the speed feedback, compared with the speed feedback, the load feedback will realize the compensation prediction in advance. Then the load feed-forward-speed feedback will make the diesel engine have a better speed running curve. For the marine power system, the generator will run directly with load, and there is no ideal three-phase power grid on land, so the load torque can be identified directly by detecting the load current, and then the control of the diesel engine actuator can be completed in advance, as shown in Fig. 4. It can be seen from Fig. 4 that when the load changes, the difference between the load feed-forward and the output torque of the diesel engine is used as the advance input control signal of the diesel actuator, so as to realize the adjustment of the fuel supply, and the diesel engine speed will also be controlled in advance, thereby reducing the fluctuation of the speed and reducing the overshoot of the speed. The existence of speed feedback further assists the load feedforward to help realize the fine-tuning of the speed control, thereby making the system control accuracy higher. It is worth noting that the difference between the load torque and output torque in the figure is not necessarily 0 due to the existence of loss after the system is stable, so it is also necessary to find the power factor when the generator is running under load, and then multiply the output torque value of the diesel engine by the difference between the power factor and the load torque is used as the advance control signal of the actuator.

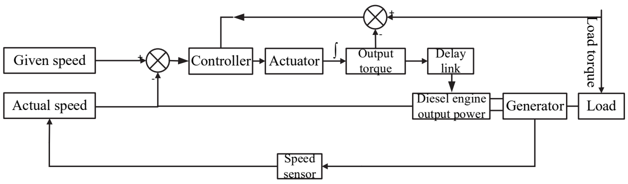

Figure 4 Diesel generator feed forward control schematic diagram

4. SIMULATION ANALYSIS OF CONTROL ALGORITHM BASED ON DIESEL ENGINE GOVERNOR

4.1 Simulation Analysis Based on Fuzzy Adaptive PID Control Algorithm

Set working conditions:
(1) Within 0 - 3 s, let the diesel generator set start without load; within 3 s, suddenly add 100% load.
(2) Within 0 - 1 s, let the diesel generator set start with no load; in 1 s, suddenly add 100% load; in 3 s, suddenly reduce 100% load. For the convenience of analysis, normalize the ordinates of all simulation result graphs.

$$m^* = \frac{m_{actual\ value}}{m_{rated\ value}} \tag{13}$$

In the formula: m^* is the per unit value of each parameter of the diesel generator set.

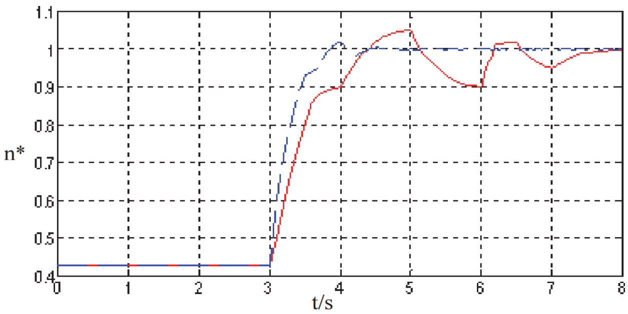

Figure 5 Diesel engine speed output curve under sudden load

From Fig. 5, it can be seen that within 0 - 3 seconds, the motor operates at a no-load speed of 0.4285. According to the optimal operating speed curve, the motor should operate at a speed of 300 rpm, corresponding to a standard unit value of 0.43, which meets the requirements. At 3 seconds, a sudden 100% load is applied. According to the principle of optimal speed operation, the motor speed will vary accordingly. As shown in Fig. 3 and Fig. 4, the electronic governor using adaptive fuzzy PID control has stable speed at 4.2 seconds, and the maximum overshoot value of 0.02 is achieved at 4 seconds. The existing electronic governor only stabilizes at 8 seconds, and the dynamic characteristics of the speed during this period are very poor. At 6 s, the speed overshoot reached its maximum value of 0.1.

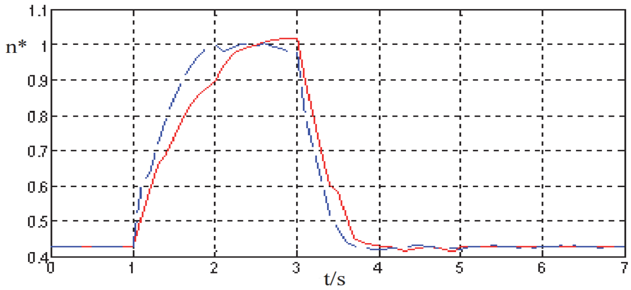

Figure 6 The speed output curve of the diesel engine when the load is suddenly increased first and then suddenly decreased

From Fig. 6, it can be seen that the sudden increase of 100% load has been analyzed in Fig. 5. This simulation mainly focuses on the sudden discharge of 100% load. From the simulation curve, it can be seen that the system under the adaptive PID controller enters the stable zone in 4 seconds, but the system under the existing governor enters the stable zone in 4.8 seconds. Therefore, the dynamic response of the governor under the adaptive PID control is faster than that of the existing governor.

In Fig. 5 and Fig. 6, the red lines represent the output curves of conventional PID controllers, and the blue lines represent the speed output curves of fuzzy adaptive PID controllers.

It can be seen from Fig. 5 and Fig. 6 that when the system suddenly increases or decreases the load, the system speed using the fuzzy adaptive PID controller enters the stable range earlier, and the system has smaller speed fluctuations and better dynamic characteristics.

However, when the load is suddenly reduced, the system under the adaptive PID controller is completely stable only at 7 seconds, while the system of the existing governor is completely stable at 5.2 seconds, so the adaptive PID controller has a longer adjustment time than the existing governor. The main reason is that the proportional adjustment coefficient K_p of the controller is a parameter that mainly affects the control stability. The larger the value, the shorter the adjustment time, and the input e of the fuzzy control will affect the size of K_p in real time. Since the flywheel of the diesel engine is a large inertia accumulator with hysteresis, the value of K_p will become smaller when the system tends to the stable area. Adjustment time is longer.

4.2 Simulation Analysis of Optimization Algorithm Based on Fuzzy Adaptive PID Control

Set working conditions:
The experimental conditions are the same as the simulation analysis based on the fuzzy adaptive PID control algorithm.

The red lines in Fig. 7 and Fig. 8 represent the output curves of the conventional PID controller system, and the blue lines represent the speed output curves of the controller system after fuzzy adaptive PID optimization.

From Fig. 7a, it can be seen that when the blue line changes load at 3 seconds, the output power of the diesel engine approaches the stable region at 3.5 seconds, while the red line approaches the stable region at 4 seconds. This is because when the load changes, the conventional PID controller has not yet detected the load change through the speed difference, while the fuzzy adaptive PID optimized controller has already detected the load change in advance based on the load difference, and then provides electrical signals to control the torque output of the diesel engine through the controller.

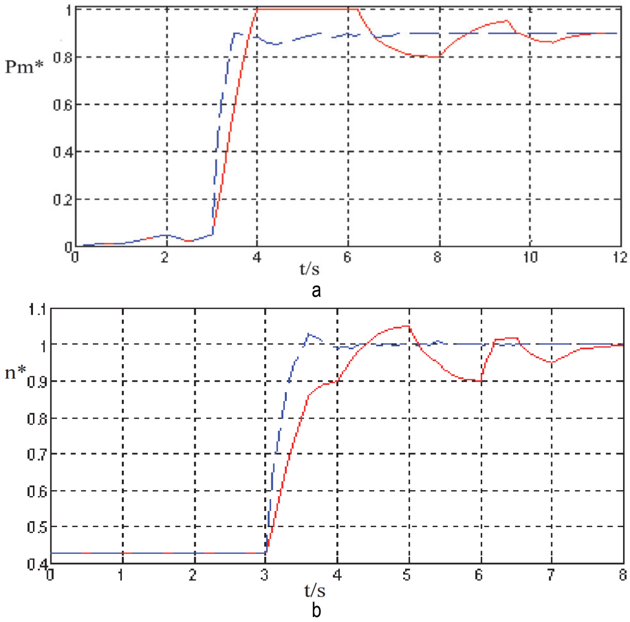

Figure 7a) diesel engine output power at sudden load b) diesel engine speed characteristics at sudden load

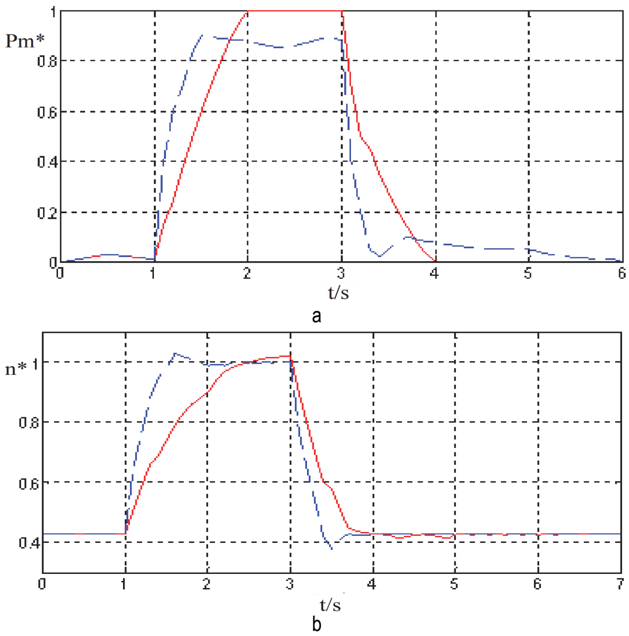

Figure 8 a) The output power of diesel engine when the load is suddenly increased and then suddenly decreased b) The speed characteristics of the diesel engine when the load is suddenly increased and then decreased

As shown in Fig. 7b, the blue line speed approached the stable region at 3.5 s, with an overshoot of 0.02. The red line speed gradually approached the stable region at 8 s, with an overshoot of 0.1.

From the simulation curve in Fig. 8a, it can be seen that after a sudden reduction of 100% load, the response speed of the output power of the blue line diesel engine is significantly faster than that of the red line diesel engine. As shown in Fig. 8b, the speed of the blue line approaches the stable region at 3.5 s, while the speed of the red line gradually approaches the stable region at 5 s.

It can be seen from Fig. 7 and Fig. 8 that when the system suddenly increases or decreases the load, the system using the fuzzy adaptive PID optimized controller not only has a faster dynamic response than the system using the conventional PID controller, but also has smaller overshoot. The adjustment time is shorter and the steady-state characteristics of the system are better.

By comparing the blue lines in Fig. 5 and Fig. 7b, it can be seen that when the system suddenly applies 100% load, the stable time of the governor speed controlled by fuzzy adaptive PID is 4.2 seconds, and the stable time of the controller optimized by fuzzy adaptive PID is 4 seconds. The latter has a shorter time to reach steady state; and the peak value of the former during the sudden load speed adjustment process is 1.03, while the latter is 1.02. The instantaneous overshoot rate of the former is higher than that of the latter.

Comparing the blue lines in Fig. 6 and Fig. 8b, it can be seen that when the system suddenly reduces 100% load, the stable time of the governor speed using fuzzy adaptive PID control is 5.2 seconds, and the stable time of the controller after using fuzzy adaptive PID optimization is 4 seconds. The latter has a shorter time to reach steady state; and the overshoot of the former during sudden load reduction speed regulation is $0.43 - 0.40 = 0.3$, while the latter is $0.43 - 0.41 = 0.2$. The instantaneous overshoot rate of the former is higher than that of the latter.

5 CONCLUSIONS

This paper studies the optimal operating speed of diesel generator sets, deduces the calculation formula of the optimal operating point, and designs the optimal operating speed curve of the diesel engine in combination with the calculation formula and the actual rotational speed of the diesel engine. The fuzzy adaptive PID controller and the fuzzy adaptive PID optimized controller were researched and designed respectively, and the simulation analysis of the MATLAB simulation platform was used to verify that the performance of the controller using the two control algorithms is better than that of the conventional controller. However, the speed control system optimized by the fuzzy adaptive PID control algorithm has a better dynamic response in the diesel generator system, smaller speed fluctuations, and shorter Adjust time, better control accuracy. However, due to the limitation of time and test conditions, there are still many problems worthy of further study in this paper: the mathematical model of variable speed diesel generator set can be further optimized to calculate the losses under different working conditions, so that the calculated optimization value is closer to the actual optimal operating speed value. Generally, multiple diesel generator sets are required to operate in parallel in the marine power system. Therefore, it is necessary to study the parallel operation characteristics of diesel generator sets and design the control method of power (active power, reactive power) distribution.

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