Research on Torque Control System Based on Fuzzy Logic

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Abstract: Aiming at the needs of intelligent coal mining and construction of intelligent mines, based on fuzzy control language, the torque parameter control system of intelligent drilling rigs is analyzed and researched. The structure of the torque output fuzzy control system and the fuzzy adaptive PID controller are designed, and the system is simulated. The simulation research provides new ideas for the development of actual hardware controllers in the future, and lays the foundation for realizing unmanned operations in coal mines.

1. Introduction
Ensuring coal mine safety is always the top priority of coal mining work. With smart mining [1] and smart mine [2], coal-related companies have increased the research and development of coal mine automation and intelligent equipment. In this paper, based on the construction characteristics of the intelligent drilling rig in underground tunnels of coal mines, based on the fuzzy control language, a trial analysis and research on the torque parameter control system of the intelligent operation drilling rig is carried out.

2. Control system mechanism
Fuzzy control can effectively solve the problems that traditional control methods are difficult to solve or realize. It does not need to establish a precise mathematical model of the controlled object, has strong adaptability, and has a series of advantages such as more intelligent control process. Fuzzy controller is the core of fuzzy control system. The key to its design is to find suitable fuzzy control rules for the controlled object. The form and quantity of input variables and output variables can be determined according to the actual situation of the controlled object. Normally, the input variable is the error and error rate of change between the output variable and the given variable, and the output variable is the change of the controlled object variable.

2.1. Torque output fuzzy control system structure
The rotary output system of the drilling rig controls the flow output by changing the motor power when the speed is higher than the rated gyrorator speed to ensure proper rotary torque. The input variable is the deviation value of the given power and the current output power and the rate of change of the power, and the output variable is the slewing torque. The model structure is shown in Figure 1.
The method to realize the fuzzy controller is to convert a series of fuzzy control rules offline into a query table [3], which can be used for online control. The dimension of the fuzzy controller studied in this paper is a three-dimensional fuzzy controller. Its output variable dynamic characteristics and the advantages of relatively simple control rules and algorithms have been embodied. The fuzzy control rules adopt the inference synthesis method, that is, according to the existing input, the output data is synthesized by fuzzy inference to obtain fuzzy control rules.

2.2. Design of fuzzy adaptive PID controller

PID control is proportional, integral and derivative control. According to the proportional, integral and derivative system, the appropriate output control parameters are calculated. The most common adjustment method in the control process is to achieve the purpose of closed-loop control by modifying the control variable error [4]. The PID control algorithm is as follows:

\[ u(t) = k_p e(t) + k_i \int_0^t e(t) dt + k_d \frac{de(t)}{dt} = k_p e(t) + k_i \sum e(t) + k_d \Delta e(t) \]  \hspace{1cm} (1)

- \( u(t) \) —— Output Variables of PID Controller;
- \( e(t) \) —— Error of input variables;
- \( \Delta e(t) \) —— Error rate of change of input variables;
- \( k_p \) —— proportionality factor;
- \( k_i \) —— integral coefficients;
- \( k_d \) —— differential coefficient.

Combine the PID controller with the fuzzy control system to form a new fuzzy adaptive PID controller as shown in Figure 2:
Among them, the error $e$ and the error rate of change $\Delta e$ are input variables; $r(t)$ represents the given value; $y(t)$ is the adjusted output. $\Delta kp$, $\Delta kl$ and $\Delta kd$ are the adjusted values of proportional, differential and integral coefficients respectively.

3. Fuzzy Direct Torque Control System Structure

Through a series of simulation experiments in the early stage, it is found that if the error division is not fine enough and sometimes the same space voltage vector is selected, it will cause the motor torque to react slowly and the pulsation is too large. Based on these problems, the deviation of the motor torque and the rotor flux linkage and the interval where the flux linkage is located are reasonably divided into fuzzy levels, and the voltage vector selection table of the converter is refined to select a more accurate space voltage vector. Then use the fuzzy PI controller to replace the traditional PI controller to dynamically adjust the relatively optimal PID parameters. The fuzzy DTC system of the motor converter is designed. This method can effectively accelerate the response speed of the motor torque and reduce the torque ripple of the motor, which will improve the performance of the system to a certain extent.

![Figure 3 Fuzzy DTC control system structure diagram](image)

The fuzzy DTC system is shown in Figure 3. A fuzzy PI controller and a fuzzy controller combined with a PI controller are used to form a fuzzy PI controller to adaptively adjust $P$ and $I$ parameters to achieve the best parameter values at different moments. The fuzzy space voltage vector is used. The selector replaces the traditional space voltage vector selector to determine a more accurate space voltage vector, thereby selecting a more subdivided voltage vector to improve the performance of motor control.

4. Simulation of Direct Torque Control System

According to the mathematical model, in the MATLAB/Simulink simulation environment, the motor parameters used in the simulation are: rated power 137kw, voltage 660V, and the constructed simulation module is shown in Figure 4.
The simulation results are as follows.

Figure 4 Fuzzy DTC system simulation module

Figure 5 Fuzzy DTC torque curve
5. Conclusions
In order to comply with the development direction of automation and intelligentization of underground equipment in coal mines, based on fuzzy control language and strategies, this paper studies the torque AC excitation doubly-fed motor DTC system of intelligent tunnel drilling rigs. The voltage of the fuzzy DTC system is stable and the feedback is accurate. The fuzzy control DTC system responds quickly, tends to be stable and fast, and the overall system performance is high, which provides a basis for the development of actual hardware controllers in the future.

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