The development of the motor and its speed regulation method

Jingqiao Yang

Department of Electrical Engineering, North China Electric Power University (Baoding), Baoding, China.

jingqiayang@ncepu.edu.cn

Abstract. This paper first describes the types of motors and the corresponding speed regulation methods, and then introduces the motor speed regulation. PWM is regulated by PID, which regulate it from the beginning of the emergence of the parameters k_p, k_i, k_d of the PID according to the empirical adjustment, to later development to adjust the parameters of the PID according to modern optimization algorithm. In this way, parameter control becomes accurate. Thus, the speed control of the motor is faster, which is of great significance for the application and development of the motor.

Keywords: Motor type, Motor speed control, PWM, PID control, Modern optimization algorithm.

1. Introduction

With the development of industry and automation, electric motors have been increasingly used in various fields [1], such as intelligent robots, new energy vehicles, industrial robotic arms, crane towers, intelligent balance vehicles, electric vehicles, etc., which are common in daily life. Therefore, it is of great significance to study the speed regulation method of electric motor and to regulate the speed of electric motor accurately [2]. Since people started to study motor speed regulation methods, PID control regulator with optimized motor parameters has always been a hot spot for research, which can improve the efficiency of people in daily life, scientific and technological research and development, industrial production and other fields, making the motor work more efficiently [3].

2. Motor type

More types of motors have emerged with its development, mainly of the following types.

Classification by working power: According to the different working power of the motor, it can be divided into DC motor and AC motor, which is also divided into single-phase motor and three-phase motor [4].

Classification by structure and working principle: motors can be divided into DC motors, asynchronous motors and synchronous motors according to the structure and working principle. Synchronous motors can also be divided into permanent magnet synchronous motors, reluctance synchronous motors and hysteresis with cloth motors. Asynchronous motors can be divided into induction motors and AC commutator motors. Induction motors are divided into three-phase asynchronous motors, single-phase asynchronous motors and shaded-pole asynchronous motors. AC commutator motor is divided into single-phase series-excited motor, AC-DC dual-use motor and push repulsion motor. DC motors can be divided into brushless DC motors and brushed DC motors according to their structure and operating principle [5]. Brushed DC motors can be divided into permanent magnet DC motors and electromagnetic DC motors. Electromagnetic DC motors are further divided into series-excited DC motors, parallel-excited DC motors, other-excited DC motors, and compound-excited DC motors. Permanent magnet DC motor is divided into rare earth permanent magnet DC motor, ferrite permanent magnet DC motor and Alnico permanent magnet DC motor.

Classification by starting and running mode: motors can be classified into capacitor-started single-phase asynchronous motors, capacitor-running single-phase asynchronous motors, capacitor-started running single-phase asynchronous motors, and split-phase single-phase asynchronous motors according to starting and running mode [6].

All kinds of motors are manufactured for speed controlled, so the speed control performance of the motor is very important. The speed control performance of the motor directly affects whether the action of the motor can operate according to the mode set by people. The correct and precise implementation of motor control is a direct factor affecting the efficiency of the operation of automatic devices and industrial production equipment. For the evaluation of DC motor performance, the indexes usually concerned are motor speed and electromagnetic torque, corresponding to these two indexes, the motor with excellent torque characteristics can be described as the following two points.

(1) Good speed regulation performance. DC motors with PID speed regulation have small overshoot, short rise time and regulation time, and good dynamic response characteristics [7].

(2) High starting torque. DC motors have a large starting torque and can reach the rated speed.

3. Motor speed regulation method

In a short period of time, thus bringing a lot of convenience to the motor speed regulation.

When the motor is controlled for speed regulation, disturbances may appear at any time. At the same time, there is often a relatively high precision requirement for the control effect of the motor. Therefore, closed-loop control is usually used for speed regulation. Closed-loop speed regulation is based on the deviation between the set speed and the actual speed of the motor. When the deviation exists, the microcontroller or chip will continuously adjust the duty cycle of the output PWM wave [8], so that the motor speed gradually approaches the set speed and then runs steadily. The output of the microcontroller is often a small signal, so the motor drive circuit is needed to amplify the PWM waveform output from the microcontroller as a way to drive the normal operation of the motor. This means that each specific speed of the motor corresponds to a PWM waveform with a specific duty cycle.

In practice, there is a time lag in the speed variation of the motor. Therefore, common motor control algorithms such as current feedforward control, weak magnetic control, and PID control are used in the control of DC motors to reduce the time lag. Among them, PID regulation can well alleviate the time lag problem due to mechanical inertia, and in the case of external disturbances, the use of PID control algorithms still make the motor has good speed characteristics. Therefore, PID control algorithm can be used to achieve accurate speed regulation of DC motors.

In the industrial production process nowadays, automatic control has manifested itself in the mainstream, which uses the PID control algorithm. It is simple to use, powerful and applicable to the problem, and therefore has gained great momentum and is widely used in a wide variety of control systems. The quality and effectiveness of PID control depends on matching the characteristics of the controller with those of the controlled object. In other words, the parameters of the PID controller must be adjusted to meet specific performance indicators to obtain the best control effect. So far, various methods for adjusting PID controller parameters have been proposed after research, and PID controller parameter adjustment has been developed even more.

Since 1930, PID control has been the most widely used in industrial control applications due to its excellent control effectiveness and powerful robustness. Despite the emergence of many very new intelligent control methods, PID control still dominates the main processes of industrial production [9]. However, due to the absence of specific rules for PID parameter settings, the effectiveness of PID controllers in production plants is usually poor, especially for systems with high uncertainty, which is a problem that limits the development of PID algorithms. Often, the actual system is difficult to adjust the PID parameters to some extent, which creates certain problems for the control.

PID is a combination of proportional P, integral I, and differential D. The basic control theory of PID is to use three parameters k_p, k_i, k_d for closed-loop adjustment to bring the actual value of the control system object closer to the set value. In the motor speed control system, the reasonable application of PID algorithm can better control the speed of the motor, so as to play the superiority of intelligent PID control algorithm in the motor speed control system.

In order to improve the stability of the motor from the system, k_p, k_i, k_d setting can be considered in overshoot, rise time and steady-state accuracy three aspects, from which the setting method can be obtained as follows.

The larger the proportionality factor k_p, the higher the steady-state accuracy of the motor system operation will be, which will also increase the response speed. However, this will make the motor more prone to overshoot, and when the proportionality factor is too large, it will easily cause the motor system to operate unstably. However, the proportionality factor should not be too low, because it will make the steady-state accuracy of the motor system decrease, and slow down the dynamic adjustment speed and response speed.

The integration factor k_i fills the shortcomings of the proportional factor k_p and can eliminate the steady-state error of the motor system. The value of k_i affects the steady-state error of the motor system. If it is too large, the deviation will be eliminated faster, but it will also produce integral saturation. If it is too small, the deviation will be eliminated slower, which is not conducive to the fast response of the motor regulation.

The role of the differential coefficient k_d is to forecast the deviation of the motor system in advance, which will play a certain prediction of the deviation during the motor response and prepare for the early elimination of the deviation [10].

Currently, there are two main PID parameter tuning methods commonly used. One is the early emergence of empirical tuning methods, such as damping curve methods, process response curve methods and critical vibration methods (ZN methods). This type of method algorithm is usually very simple and easy to implement. However, it lacks flexibility. The other one, based on the respective advantages and principles of computer technology and intelligent control methods, combines traditional PID control theory and computer intelligent control, and makes many intelligent improvements to adjust the reduction to fill the gap, generating the modern familiar intelligent control algorithm. The genetic algorithm optimizes and configures the PID control, and the genetic algorithm adjusts the three parameters k_p, k_i, k_d by iterations to bring the actual values closer to the set values continuously, so that the control effect meets the actual engineering requirements [11].

By analyzing the actual industrial operation and summarizing the experience and theory, we can get a more satisfactory effect of using PID control theory for the non-linear, multi-variable and strongly coupled time-domain variation characteristics of DC motor system. However, the most important influence factor for PID control algorithm has always been the adjustment of the three parameters in the PID algorithm, which is usually a tedious and complicated process, bringing many problems to the actual engineering applications that need to be solved.

But in the daily application of the commissioning process, the system performance is often unsatisfactory. At this time, the more traditional PID parameter adjustment method is used, and in many cases this process is very tedious, and it often takes a lot of time to obtain excellent control results.

Therefore, there is an urgent need to find a method of parameter self-tuning, which can save the tedious process of parameter tuning and improve the efficiency of using PID control methods. With the development of computers, multiple iterative optimization operations have gradually emerged and are able to find the optimal solution quickly [12].

In recent years, heuristic algorithms have gradually come into the limelight among modern optimization algorithms. Subsequently, many heuristic algorithms have been rapidly developed through people's research in natural fields, social sciences, etc. Heuristic algorithms are genetic algorithms, neural networks, simulated annealing, etc.

Among the heuristic optimization algorithms, genetic algorithms are far-reaching due to their wide application. Meanwhile, compared with other optimization algorithms, genetic method has several outstanding advantages as follows.

(1) The selection of good individuals is carried out using the fitness function, which eventually converges to the optimal solution.

(2) The chromosomes of each individual in the population are reorganized by crossover, inheritance and mutation, and the structure of chromosomes is constantly updated, which makes the solution of chromosome group more comprehensive.

(3) The process of optimal solution search is computed in an iterative manner, and the operation is parallelized with the chromosomes of several individuals at the same time, which makes the operation more efficient.

(4) The global search of genetic algorithm can find the global optimal solution.

Since the birth of genetic algorithm, the model theory and the corresponding algorithm implementation method have been proposed, which laid the foundation for the later development. Since then, people have been continuously studying various operators of genetic algorithms, including the encoding method of population chromosomes, the selection and improvement of the fitness function of the actual problem, the determination and modification of the corresponding control parameters, the selection method used in heritage, the cross-variance operator, the cross-variance probability and the correlation mechanism, and have made many improvements in related methods. The combination of genetic algorithms and optimization generality methods is a modern optimization algorithm created for many practical engineering problems, which can overcome the limitations in all directions and has great advantages to solve practical engineering problems.

Therefore, genetic algorithms are selected as the object of study for modern optimization algorithms. It is also of great significance to discuss the characteristics of the application of genetic algorithms in the context of speed regulation for DC motor systems and the application of genetic algorithms in the adjustment of PID parameters [13].

The study of genetic algorithms in the rectification of PID controller parameters for motor speed regulation will enhance the application of DC motor PID control theory and will play a greater role in promoting industrial production as well as scientific research and other fields.

With the combination of modern optimal control algorithms and PID control, many types of modern optimal algorithms for PID control regulators have emerged. When selecting PID control regulators for industrial production, the controller type should be determined according to the specific control conditions and control effects of the motor.

The core problem of optimizing PID controller parameters is how to tune it to obtain the best control effect [14]. At this point, the PID controller parameter optimization problem can be considered as a multi-objective optimization problem under the constraints of multiple constraints to be tuned. Since genetic algorithms are applied to multi-objective optimization, population evolution-based genetic algorithms have been increasingly recognized, and multi-objective evolutionary algorithms have begun to be widely studied and applied in engineering practice. During the development of population evolution-based genetic algorithms, multi-objective genetic algorithms have gradually become the most powerful and widely used algorithms, and have made great progress and improvement of theoretical methods in the past decade. Nowadays, the theory of genetic algorithms based on population evolution is very mature and perfect, which can basically meet the requirements of industrial development [15].

4. Conclusion

This article details the various types of motors based on the evolutionary history of motors. Among the various properties of motors, the motor speed regulation performance is very important, which represents the smoothness and stability of the motor speed regulation and the ability to adapt the magnitude of the rotating torque to the application scenario. The speed regulation of the motor relies on PWM to modulate, so the size of PWM output needs to be adjusted in real time according to the actual situation. The method of adjusting PWM is the PID algorithm, and the three important parameters of PID algorithm are proportional P, integral I, and differential D. In the early days of the

emergence of PID, the parameters were often adjusted according to people's experience, which brought about problems such as slow adjustment time and imprecise speed regulation. With the development of computer technology, modern optimization algorithms with iteration as the calculation method emerged, which can find the optimal solution globally and are fast in calculation. The most important thing is that the parameter solution is very accurate and is placed in the most appropriate solution for the PID parameters. Therefore, there are modern optimization algorithms for PID based on optimization algorithms, such as genetic algorithms, neural network algorithms, simulated annealing algorithms, to regulate the three parameters of PID. Genetic algorithms have developed rapidly due to their fast convergence and easy to grasp principles, and are also very suitable for the regulation of PID parameters. In the future development of motors and speed control methods, there will be more accurate and fast speed control methods, which are more suitable for modern industrial production applications.

References

[1] Hou C. Adaptive fuzzy control of brushless DC motor based on genetic algorithm [D]. Henan University of Science and Technology. 2013 (06).

[2] Dong S, Cheng X. A review of torque pulsation in brushless DC motors and its suppression methods[J]. Microelectromechanics. 2010(08).

[3] Chen Y, WU R. Dual closed-loop speed control system for brushless DC motor[J]. Light Industry Machinery. 2009(01).

[4] Qiu Z, Huang D, Gui W, Yang C. Research and application of fuzzy PID control system based on variable domain interpolation[J]. Journal of Instrumentation. 2008(11).

[5] Zheng H, Xu H, Zhu G. Application of variable domain adaptive fuzzy control in avionics power generation[J]. Control Theory and Applications. 2008(02).

[6] Yin Y, Zheng B, Zheng H. A simulation method for modeling brushless DC motor control system based on Matlab[J]. Journal of System Simulation. 2008(02).

[7] Qi R, Lin H, Chen M. Analysis and suppression of brushless DC motor commutation torque pulsation[J]. Journal of Electrical Machines and Control. 2006(03).

[8] Jiang H, Yang P. Fast modeling and simulation of brushless DC motor based on Matlab/Simulink[J]. Journal of Yunnan University (Natural Science Edition).2005(S2).

[9] Ji Z, Shen Y, Jiang J. A new fuzzy PI intelligent control of brushless DC motor speed control system[J]. Journal of Electrical Machines and Control. 2003(03).

[10] Zhu L, Wang Q, Xiao B. Analysis of fuzzy control system for DC brushless motor[J]. Journal of Hefei University of Technology (Natural Science Edition). 2002(06).

[11] Li J, Cui S, Li L, Ren C, Wang Y. Design and development of brushless DC motor control system based on fuzzy PID[J]. Machine Design and Manufacture.2013(02).

[12] Wang W, Zhang Y, Liu P, Lin G. Research and simulation of fuzzy PID control system for brushless DC motor[J]. Computer Simulation. 2012(04).

[13] Lei J. Modeling and simulation of fuzzy PI control system for brushless DC motor[J]. Modern Electronic Technology. 2012(06).

[14] Ni T. Application of fuzzy adaptive PID control in vector control of brushless DC motor [J]. Big Motor Technology. 2011(06).

[15] Sun X. Research on fuzzy control of brushless DC motor based on genetic optimization [J]. Coal mining machinery. 2011(10).