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DC Motor Based on MATLAB

-- Simulation Analysis of Speed Regulation System

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Abstract

With the rapid development of power electronic devices, the use of gate turn-off transistor GTO, full-controlled power transistor GTR, P-MOSFET, IGBT insulated gate transistors and some other high-power devices composed of full-controlled pulse width modulated switching transistor amplifier (Pulse Width Modulated), has gradually developed, use more widely. In the electric drive system, the regulation voltage DC converter is the most widely used as a speed control method, in addition to the use of adjustable DC voltage thyristor rectifier obtained, it can also make use of other power electronic components controllability, using thyristor modulation technology, direct modulation of a constant DC voltage into alternating polarity, size adjustable DC voltage, the DC motor armature to achieve the smooth adjustment of the voltage across constitute DC drive system. This paper discusses the open, single, double DC speed control system as well as the basic concepts of static steady state characteristics. Finally the application of MATLAB Simulink, structure-oriented electrical schematic diagram of the simulation technology, the DC speed control system is simulated and analyzed.

Keywords

DC motor, Speed regulation , Simulation.

1. Introduction

The advantages of DC motor are as follows:Good speed adjustment performance, large starting torque, large speed adjustment range, stable speed adjustment, etc.It has been playing an important role in industrial control.With the development of power technology, especially due to the emergence of high-power electronic equipment, DC current drive will replace AC drive, but permanent magnet DC power is used in low and medium power.In the circuit control is relatively simple, especially in the high-precision servo control system, DC motor is widely used to require high speed adjustment performance or large torque.The typical speed regulation system of DC power regulation system is double closed loop and current speed regulation system.In the design of DC speed regulation system, it is necessary to adjust open-loop, single closed-loop, double closed-loop, etc.It needs to observe a large number of performance, coupled with more calculation parameters, it is often difficult to get ideal results.For example, in the design program, Matlab GUI tools are used to support the design.Because the dynamic model of the controlled system can be established, the waveform of each point can be observed intuitively and quickly.In this way, the performance of the adjustment system can be improved by repeatedly modifying the dynamic model of the adjustment system without repeated removal or debugging.The dynamic simulation tool GUI is modeled in MATLAB, which makes the module composition convenient and the performance analysis intuitive.It can shorten the process of product design and development.Through the simulation analysis of DC motor adjusting system based on MATLAB, the superiority of current motor in special situation can be realized.Due to the switching nonlinearity of power electronic devices, the analysis of power electronic circuits has brought certain complexity and difficulty.Simulation technology

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provides a new method for power electronic circuit analysis.Based on Matlab graphical user interface development tool, a Windows style power electronic circuit simulation platform is constructed. Users can use the platform to analyze the working principle and set component parameters without mastering professional matlab knowledge.The theoretical operation values are calculated, and a series of convenient operations are displayed on the analog interface in real time, such as the analog waveform of human motion.

Through simulation, the model of electrical system can be described with intuitive and easy-to-use images.We can also verify the correctness of waveform analysis in some special cases through simulation, so as to better understand some concepts.

2. DC Motor Speed Control System

2.1. Open Loop Speed Control System And Its Characteristics

Thyristor motor speed control system (V-M system for short), its control system schematic diagram is shown in Figure 1.

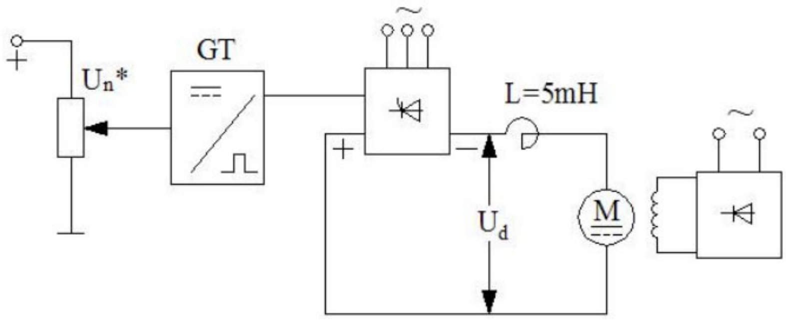

Figure 1. Schematic diagram of V-M open loop control system

The main circuit of V-M DC open-loop speed regulation system is composed of thyristor converter VT, reactor L and DC motor M.

2.2. Single Closed Loop DC Speed Regulation System with Static Error and Its Characteristics

The operational amplifier is used as a proportional amplifier (also known as proportional regulator, P regulator), as shown in Figure2.

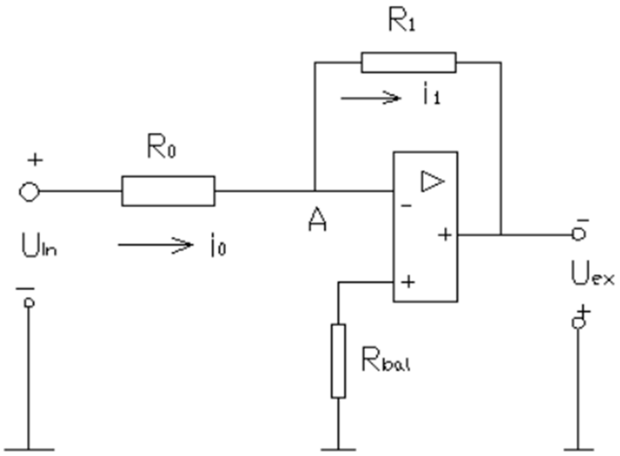

Figure 2. Proportional amplifier

U_{in} and U_{ex} Input and output voltages of the amplifier, R_{bal} Is the balance resistance of the in-phase input to reduce the influence of the offset current of the amplifier.

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$$K_p = \frac{U_{ex}}{U_{in}} = \frac{R_1}{R_0} \tag{1}$$

2.3. Speed Regulation System with Static Error and Its Characteristics

The speed regulator ASR and the current regulator ACR are set up in the double closed-loop speed control system to regulate the speed and current respectively. The two are nested, that is, the output of the speed regulator is taken as the input of the current regulator, and then the output of the current regulator is used to control the trigger device of the thyristor rectifier. Thus, the speed and current double closed-loop speed regulation system is constituted.As shown in Figure3.

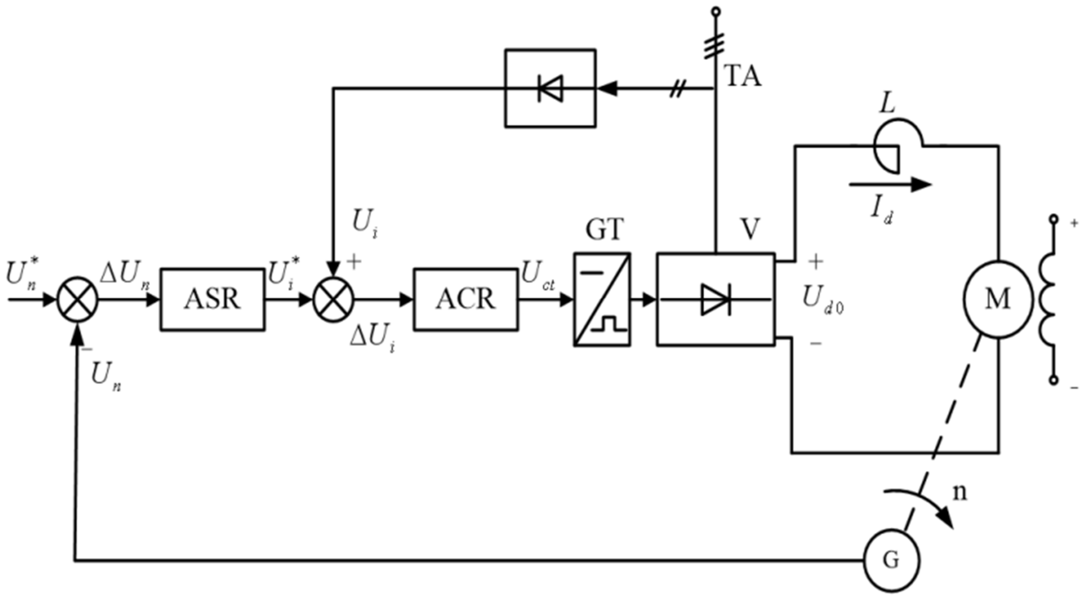

Figure 3. Structure of speed and current double closed loop speed control system

3. Simulation of Speed Control System

3.1. Modeling and Simulation of Open Loop DC Speed Regulation System

The electrical principle structure of open-loop DC speed regulation system is shown in Fig4. The system is composed of given signal, synchronous pulse trigger, thyristor rectifier bridge, smoothing reactor, DC motor and so on. Fig. 4 is the simulation model of thyristor DC speed regulation system composed of electrical schematic diagram method.

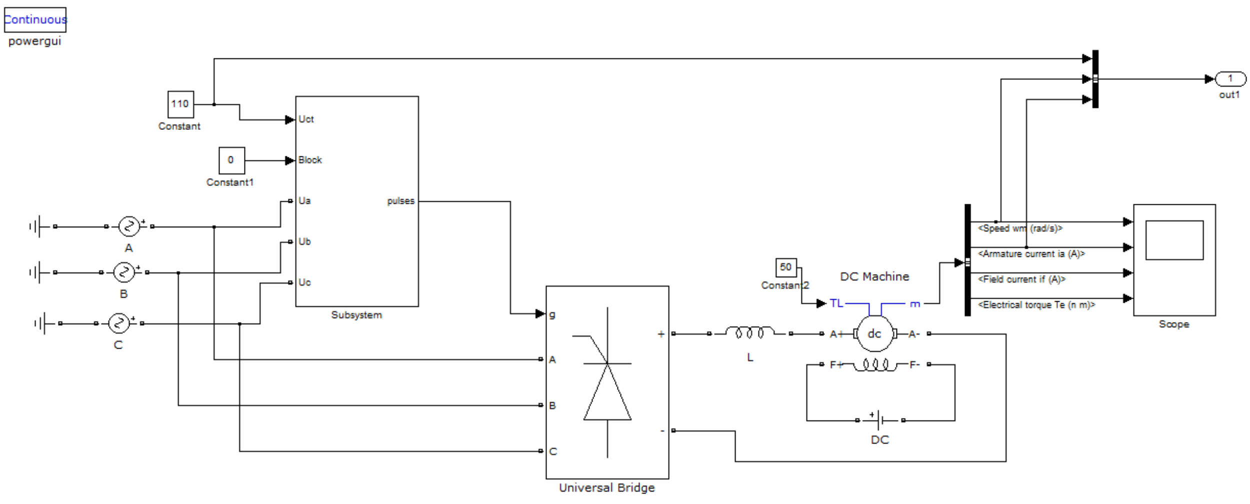

Figure 4. Simulation model of open loop DC speed regulation system

Parameter setting and calculation:

The rated parameters of DC motor are 220V,136A,1460R/min, $R_a = 0.5\Omega$, $I_f = 1.5A$, $I_f = 1.5A$, motor coefficientExcitation voltage=220 V, smoothing reactor Three phase full control bridge rectifier circuit is adopted.

According to the above data and steady-state requirements, the calculation parameters are as follows:

The effective value of rated phase voltage at secondary side of rectifier transformer is

$$U_2 = \frac{U_N + R_a I_N}{2.34\cos\alpha} = \frac{220 + 0.5\times 136}{2.34\cos 30^{\text{d}}} \approx 141V \tag{2}$$

Motor parameter calculation:Excitation resistance $R_f = \frac{U_f}{I_f} = \frac{220}{1.5} = 146.7\Omega$ .The excitation inductance can be taken as 0 under constant magnetic field control.

Armature resistance $R_a = 0.5\Omega$.The armature inductance is estimated by the following formula $U_2 = \frac{U_N + R_a I_N}{2.34\cos\alpha} = \frac{220 + 0.5\times 136}{2.34\cos 30^{\text{d}}} \approx 141V$ .Mutual inductance between armature winding and excitation windingIt can be calculated according to the following steps.Torque coefficient $C_m = \frac{30}{\pi} C_e = 30\times 0.132/\pi = 1.26$ .Then armature winding and excitation winding are mutual inductance $L_{af} = \frac{C_m}{I_f} = \frac{1.26}{1.5} = 0.84H$ .Motor moment of inertia $J = \frac{GD^2}{4g} = \frac{22.5}{4\times 9.8} = 0.57\text{kg}\cdot m^2$.Rated load torque $T_L = \frac{30}{\pi} C_e I_N = 9.55\times 0.132\times 136 = 171N\cdot\text{m}$.

The design of each module is as follows:

(1)Parameter setting of AC power supply: the AC phase voltage of the three-phase power supply is 142v, the frequency is 50 Hz, and the initial phase phase of phase A is set toPhase difference of three phases.

(2)SCR rectifier bridge parameter setting: the number of bridge arms is 3, ports a, B and C are set as input terminals,"Power electronic device" is selected as "thyristor", others are the default values.

(3)Parameter setting of smoothing reactor: in the "series RLC branch" module, the

(4)Parameter setting of DC motor: the voltage of excitation power supply is set as 220 V, and the parameters of motor adopt the above calculation results.

(5)The frequency of the 6-pulse trigger is set to 50 Hz and the pulse width is 10Check "double adding".

(6)The given speed voltage is set at 150V.

(7)Simulation time is 234.

After the parameter setting is completed, the simulation starts. The running icon in the MATLAB model menu of the motor starts the simulation, and the simulation results can be output after the simulation.

After double-click the oscilloscope command, observe the simulation waveform of DC motor speed, current, torque and other signals through the oscilloscope module, as shown in Fig. 3-2. The simulation waveforms of motor speed, armature current, excitation current and electromagnetic torque are respectively shown in the diagram from top to bottom.

The mechanical characteristic can be obtained by inputting the command in MATLAB (n-2).
Input drawing command: set (0, 'showhiddenhandles','on') set(gcf,'menubar','figure')
Figure 2 can be used to output more graphics, such as Figure 5.

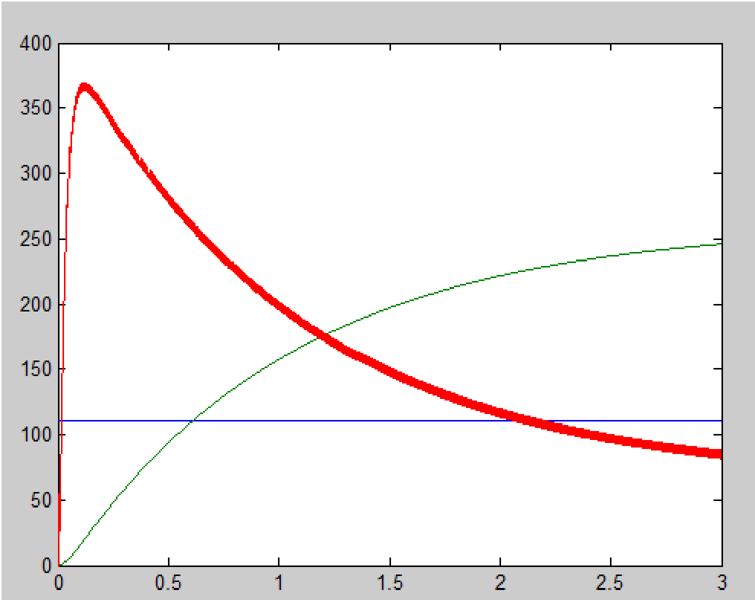

Figure 5. Simulation waveform of open loop speed control system

Analysis: it can be seen from figure 6 that when the given voltage is 110V, when the DC motor is just started, the starting current suddenly increases to 820a, and the speed rises quickly. After that, the current begins to decline, the speed continues to rise, and finally it stabilizes and cannot return to the previous speed, and the current of the electromotor armature decreases and stabilizes.It can be seen that the speed of open-loop DC speed regulation system is not controllable.

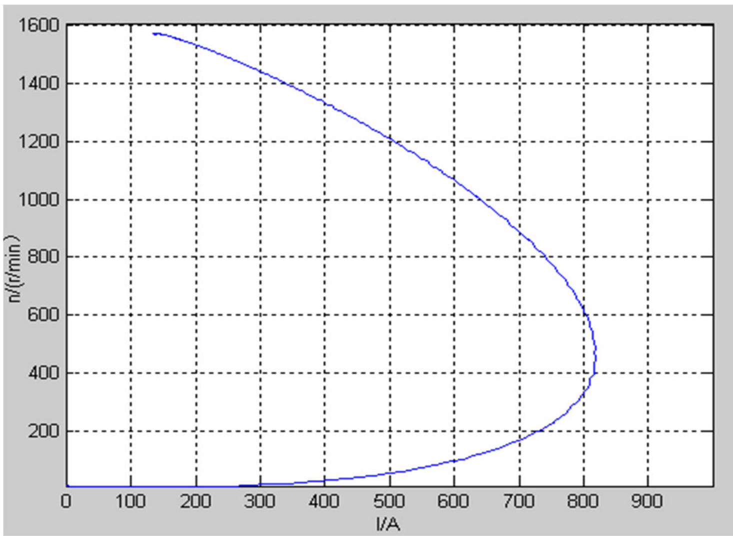

Figure 6. Open loop mechanical characteristic curve

Conclusion: from Figure 6, it can be concluded that the machine characteristic curve of open-loop is a line with large radian, and the machine features soft and anti-interference function is not good.

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3.2. Modeling and Simulation of Single Closed Loop DC Speed Regulation System with Static Error

When the motor load increases, the rotation speed decreases, the speed feedback decreases, the speed difference increases, the output of the amplifier device increases, and the transmission electric value and armature power of the rectifier device are improved through the phase-shifting trigger device.Then the electromagnetic torque of the motor increases and the rotation speed increases, which compensates for the decrease of the rotation speed caused by the load increase.

The steady-state formula of the DC regulating speed device with negative feedback of rotating speed is $n=\dfrac{K_pK_sU_n^*-I_dR}{C_e(1+K)}$, and the rotation speed is reduced to $\Delta n=\dfrac{I_dR}{C_e(1+K)}$, where $K=\dfrac{K_pK_s\alpha}{C_e}$, from the stable characteristic formula, if the amplification is increased appropriately, the electric power

If the speed of the machine is reduced to a decreasing degree, the motor will have many mechanical characteristics.In a word, when the load changes, the rotation speed of the motor will decrease, and the motor will form a more perfect stable function. If the amplification factor is increased, the operation of the device will also cause instability. According to the analysis Figure 3-3, the simulation mold of single closed loop negative feedback adjusting speed device is constructed.Compare the speed adjustment device with the open loop device. The difference between the devices focuses on the control circuit.See Fig 7 for simulation mold of DC speed adjusting device with single closed loop static difference.

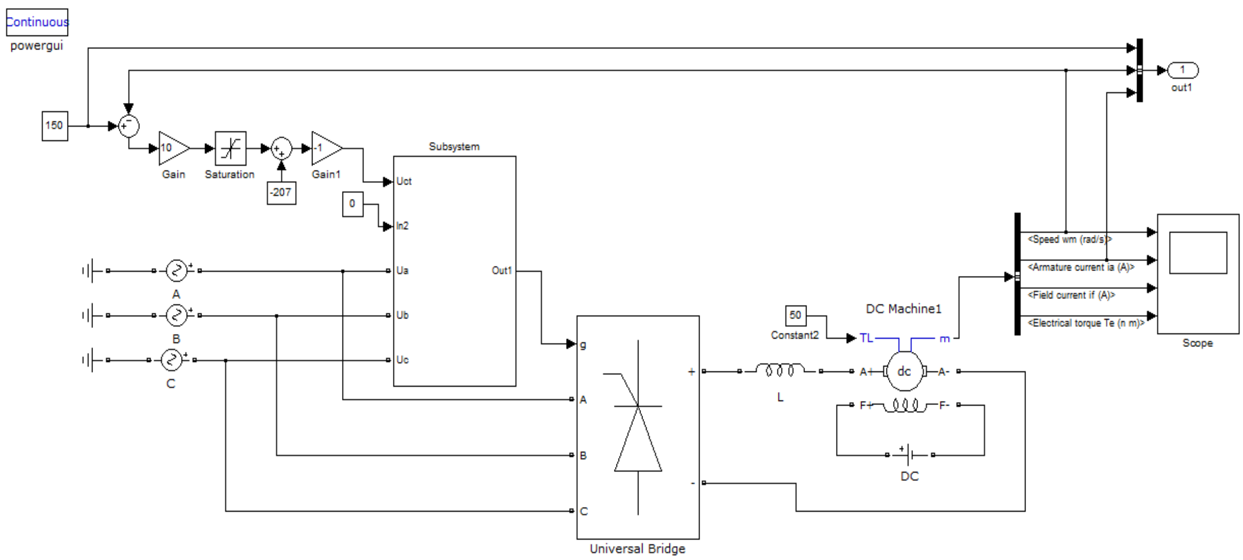

Figure 7. Simulation model of single closed loop DC speed regulation system with static error

The control circuit of single closed loop speed regulation system with static difference is composed of given signal, speed regulator and speed feedback. A limiter is added as needed.

The speed regulator of speed regulation system with static difference adopts proportional regulator. When the given signal is positive, the output signal of the amplifier is reversed, and then it is used as the phase-shifting control signal of the synchronous trigger after passing through the limiter.

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Parameter setting: The given signal is set as 150V and the speed feedback coefficient is set $\alpha = 0.102$ .The range of the limiter is [- 40,40], magnification $K_p = 5$ and $K_p = 30$ The speed response curve is shown in Fig 8.

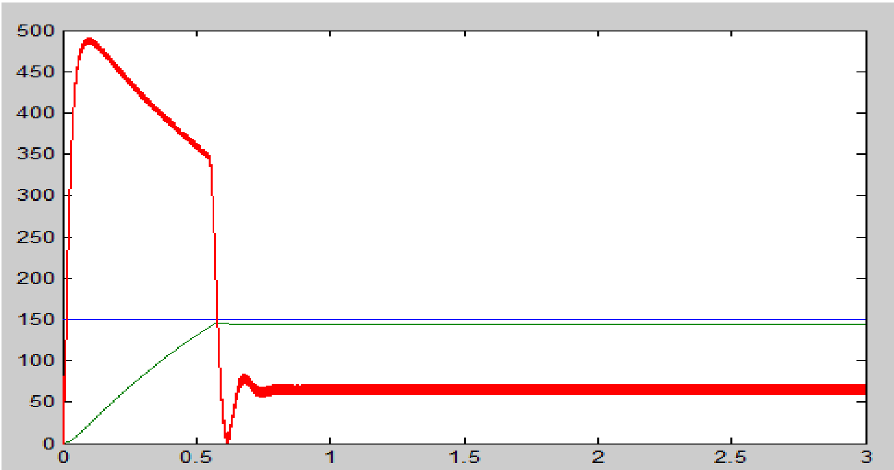

Figure 8. Smulation waveform of speed regulation system with static difference

Analysis: it can be seen from figure 9 that under the condition of given parameters, the speed of the motor reaches 1450r / min. due to no current limiting measures, the current in the starting process is very large, reaching 820a. Such a large starting current is easy to burn the motor, and it is not allowed for thyristor rectification with low overload capacity.

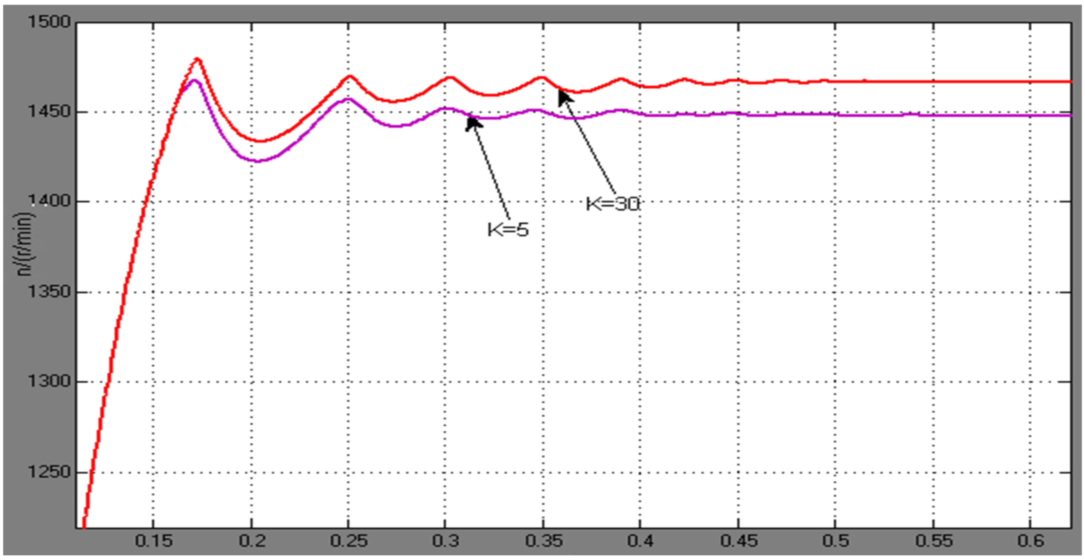

Figure 9. Speed response curve at k = 5 and K = 30

Analysis: it can be seen from figure 10 that with the increase of magnification, the speed drop decreases. Although the system speed increases, the larger the magnification is, the better.129)e final speedk) < 129k) < 129, the system is stable $n*$; in $K_p \geq K_{pcr}$ The control system is unstable and the speed response simulation curve is in an unstable state, as shown in Fig. 10.

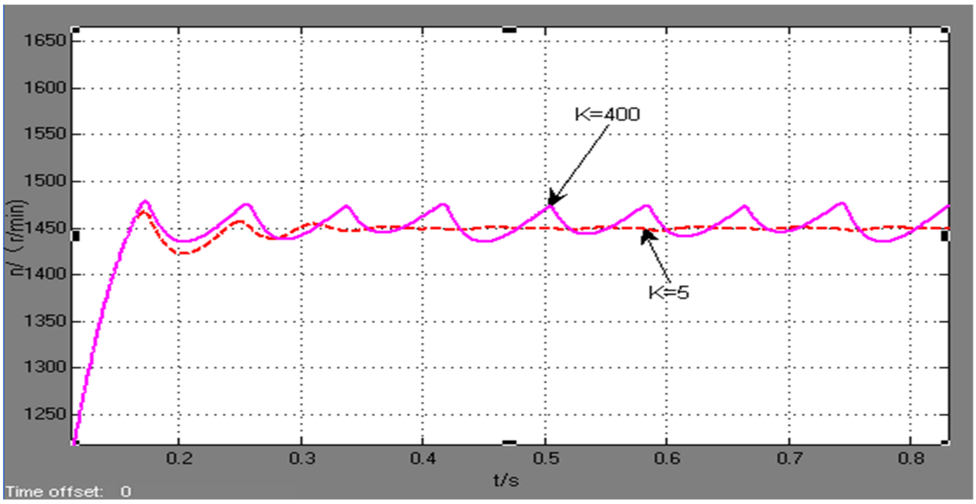

Figure 10. Speed response curve at k = 5 and K = 400

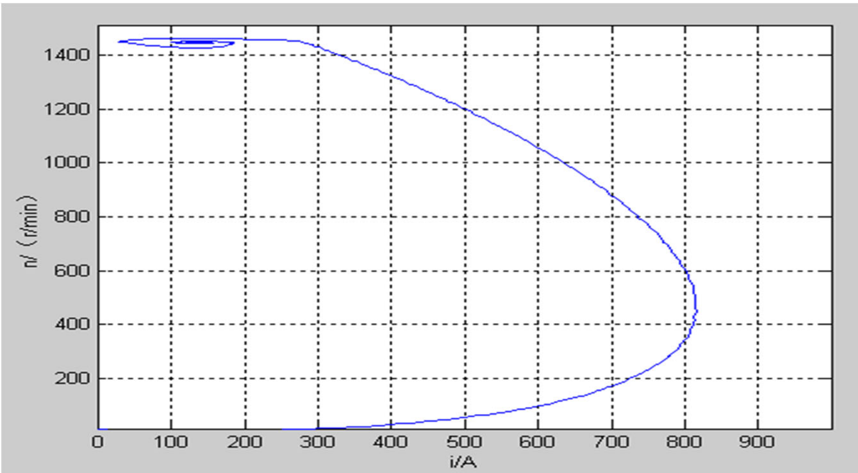

Figure 11. Simulation curve of static characteristics with static error

Analysis: it can be seen from figure 2-8 that the static characteristic curve of the closed-loop system is much harder than that of the open-loop system by comparing the mechanical characteristics of the open-loop system with the static characteristics of the closed-loop system, which can improve the speed regulation range under the requirements of ensuring a certain static error rate.

3.3. Modeling and Simulation of speed and current double closed loop speed control system

The double closed-loop speed control system can make full use of the overload capacity of DC motor, which makes the motor run at the maximum allowable current during the start-up process, and the inner current loop also improves the dynamic performance of the system. According to the engineering design method, the quantitative simulation of the regulator parameters is determined, as shown in Fig. 12.

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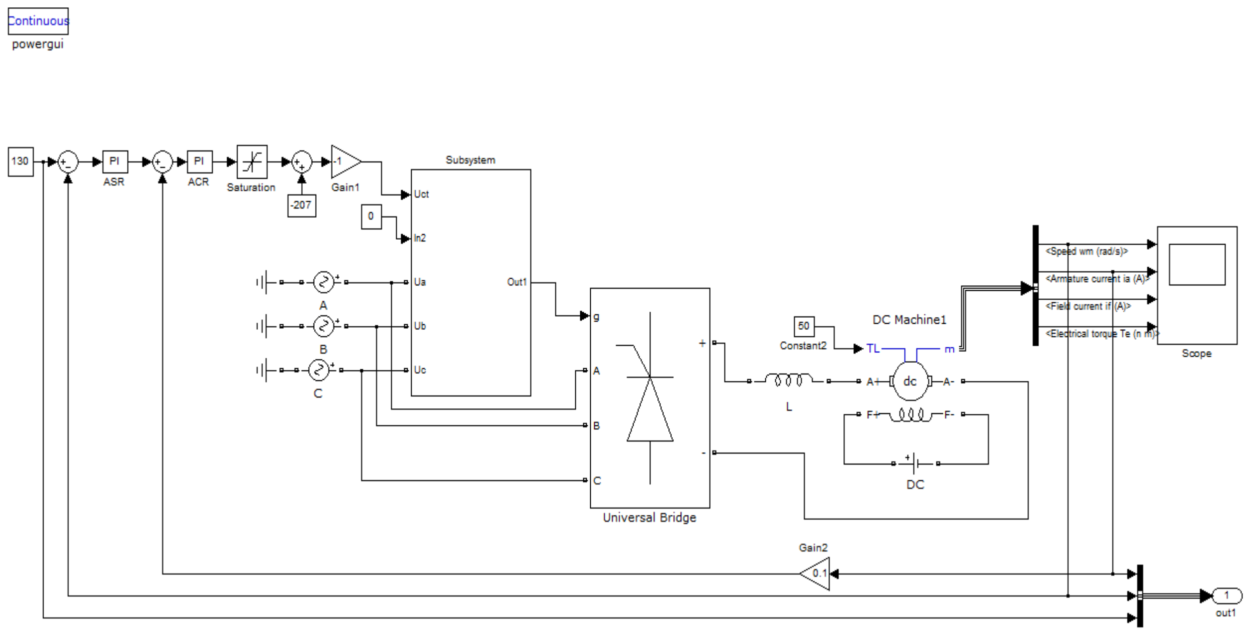

Figure 12. Simulation model of speed and current double closed loop speed regulation system

Parameter setting:

The control circuit consists of PI regulator, filter module, speed feedback and current feedback.The parameters of speed regulator ASR and current regulator ACR are calculated according to engineering design method, namely ASR

$K_{pn} = 6.02$, $K_n = \frac{1}{\tau_n} = 11.494$, ACR's $K_{pi} = 0.43$, $K_i = \frac{1}{\tau_i} = 58.823$ The upper and lower limits are taken as [10 - 10].

The parameter of speed feedback coefficient with filter is set as follows: numerator is [0.01], denominator is [0.01 1]. Parameter setting of current feedback coefficient with filter: numerator is [0.121], denominator is [0.002 1].Parameter setting of speed delay module: numerator is [1], denominator is [0.01 1].Parameter setting of current delay module: numerator is [1], denominator is [0.002 1].

2 tbode is used as the start time and end time.

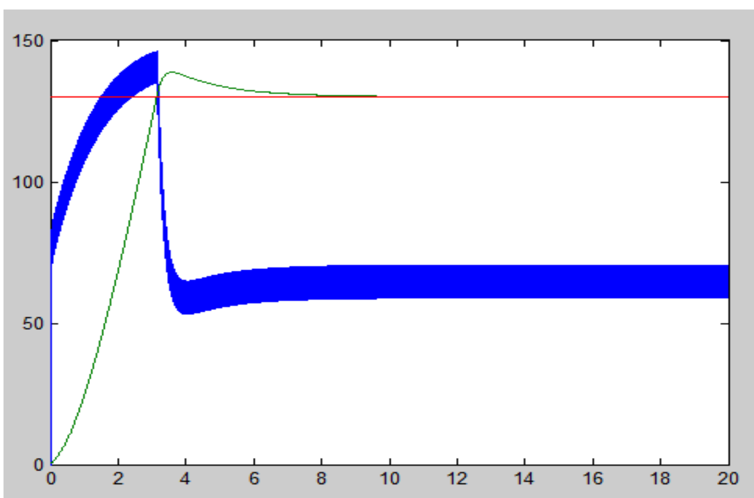

Figure 13. Simulation waveform of speed and current double closed loop regulation system

Analysis: it can be seen from the simulation results in Fig13 that when the constant signal is 10V, the armature current of the motor under the action of the current regulator approaches the maximum value during the starting process of the motor, which makes the motor start to rise with the optimal time criterion. When the speed is about 0.25s, the speed is overshoot, and the current drops quickly. It reaches the steady state at 1.4s, and the speed is 1000r / min in the steady state, The whole change curve is very similar to the actual situation.

4. Conclusion

Through this paper, the DC speed regulation system, especially the single and double closed loop DC speed regulation system, is simply understood. The static and dynamic characteristics of single and double closed loop DC speed regulation system are understood. These properties are well verified by simulation and experiment.

DC motor is often used as power in the field of high requirements for speed regulation performance, but the steady state performance of DC motor open loop system can not meet the requirements. In order to eliminate the static error of the system, be used instead of proportional regulator.

DC speed regulation system is also the basis of motion control system. Starting with DC speed regulation system, on the basis of establishing a solid concept of DC control system analysis and design, the AC system is studied. In this way, we can better master the analysis and design of AC speed regulation system.

For a long time, DC speed regulation system has been widely used in industrial production process with its excellent performance. In recent years, with the development of high power transistor technology, DC pulse width modulation system with high power transistor as switching device has become a new development direction of DC speed regulation system. Along with the development of computer technology, especially single chip microcomputer technology, digital DC PWM speed regulation system is attracting more and more attention because of its advantages of simple control and flexible change of control scheme.

Acknowledgements

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