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Simulation Technology in the Reform and Exploration of Teaching in the "Electric Drive Automatic Control Systems" Course

Ting Yang[1,a,*], Renjie Qi[2,b], Yan Li[1,c], Jing Zhang[1,d], Xiong Wang[1,e], Yangyang Xie[1,f]

[1]*School of Energy Engineering, Yulin University, Yulin, 719100, China*
[2] *School of Electrical Energy and Power Engineering, Yangzhou University, Yangzhou, 225127, China*
[a]*yt1028@yulinu.edu.cn,* [b]*328986726@qq.com,* [c]*yezi0117@163.com,* [d]*67966105@qq.com,*
[e]*12296832@qq.com,* [f]*2508732634@qq.com*
[*]*Corresponding author*

Abstract: *This article first analyzes the characteristics of the Electric Drive Automatic Control Systems course and the difficulties faced by local application-oriented colleges. To better ensure the teaching effect, MATLAB, an important tool, is introduced into the teaching process. Secondly, a current closed-loop DC speed control system powered by a PWM converter is constructed under the Matlab/Simulink simulation platform. The simulation results verify the correctness and rationality of the engineering design method, allowing students to more intuitively understand the difficult parts of this course. Finally, through teaching practice, it is proven that after introducing the Matlab/Simulink simulation platform, the teaching effect is good, and the enthusiasm of students' learning has been greatly improved.*

Keywords: *Electric Drive Automatic Control Systems; Matlab/Simulink; DC speed-regulating system*

1. Introduction

"Electric Drive Automatic Control Systems" is an important comprehensive professional course in the field of electrical engineering and its automation, which requires students to have a very good grasp of power electronics technology, automatic control principles, electromechanics, and other courses. It is a course that highly integrates theory with practice [1-5]. The "Electric Drive Automatic Control Systems" course includes open-loop and closed-loop DC speed control systems, double closed-loop DC speed control systems of speed and current, asynchronous motor speed control systems based on steady-state and dynamic models, as well as variable voltage and frequency speed control systems for synchronous motors and servo systems. This course has strong comprehensive knowledge, a wide coverage, close connection between theory and practice, and strong engineering practicality. It is a course that equally emphasizes both theory and practice. However, there are two difficulties in achieving full coverage of the experimental course: (1) For local colleges, the cost is too high to achieve. (2) During the experimental process of this course, the internal adjustment of various components is very short-lived and cannot be directly measured. In view of the above difficulties, it is very necessary to develop simulation experiments for teaching.

Known MATLAB is an important tool for modern scientific research. By establishing virtual models based on MATLAB, various internal variables can be intuitively extracted for easy viewing. It ensures the experimental results while presenting internal parameters intuitively, and it also allows for the self-setting of related control parameters to understand the actual role of different parameters during operation, assisting in teaching. The virtual simulation platform based on MATLAB can also help students to implement their own control methods in a very simple way and at a very low cost, without any changes to the hardware. This not only enhances students' programming skills but also stimulates their enthusiasm for innovation [6]. Therefore, introducing the MATLAB tool into the teaching of electric drive control systems is not only to let students master a method of analyzing and designing automatic control systems, improving students' theoretical and practical levels, but also to let students master a modern scientific research method to play a role in other fields.

At the same time, by combining wisdom with labor, we can comprehensively cultivate students' overall quality and abilities, update experimental settings, transform verification experiments into

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innovative development experiments that integrate innovation, and guide students with practical engineering project construction cases to stimulate their enthusiasm and initiative in learning. This helps students understand the role of the course in their work, allowing them to experience the powerful influence of applying what they have learned and using theory to guide practice without leaving the classroom. It enables students to have strong adaptability before entering society and lays a foundation of theory, practice, and thought for their future long-term development [7].

2. Simulation Teaching Case

2.1. Design of Automatic Current Regulator (ACR)

In the Matlab/Simulink simulation platform, a current closed-loop DC speed control system powered by a PWM converter is constructed to design a high-performance system. Students are required to select the PI parameters for the ACR (Automatic Current Regulator). By observing the simulation waveforms of current loop, the control performance of the system is checked. The system parameters are provided by the textbook (the textbook used this semester) [1] as shown in Table 1.

Table 1: The system parameters.

Parameter	Value
P_N	60kW
U_N	400V
I_N	52.2A
n_N	2610r/min
Ce(emf coefficient)	0.1459V·min/r
Ks(PWM converter amplification factor)	107.5
R	0.368Ω
T_l	0.0144s
T_m	0.18s
T_s	0.000125s
T_{oi}	0.000125s
T_{on}	0.01s

Design requirements: (1) Steady-state indicators: Zero steady-state error; (2) Dynamic indicators: The overshoot of current $\boldsymbol{\sigma_i}\leq$ 5%, and the overshoot of speed when starting up to the rated speed $\boldsymbol{\sigma_n}\leq$ 10%.

To ensure that the overshoot is less than 5% and that the steady-state current has no steady-state error, the ACR can be designed according to a typical Type I system. The control object of the current loop is of a double-inertia type, hence a PI-type current regulator can be used, whose transfer function is given in (1):

$$W_{ACR(S)} = \frac{K_i(\tau_i s+1)}{\tau_i s} \tag{1}$$

ACR lead time constant:$\tau_i = T_l = 0.0144s$.

Current loop open-loop gain:To make $\sigma_i \leq 5\%, K_I T_{\sum i} = 0.5, K_I$ is calculated as follows:

$$K_I = \frac{0.5}{T_{\sum i}} = \frac{0.5}{0.00025} s^{-1} = 2000 s^{-1} \tag{2}$$

So, the proportionality coefficient of ACR is given in (3):

$$K_i = \frac{K_I \tau_i R}{K_s \beta} = \frac{2000\times0.0144\times0.368}{107.5\times0.1277} = 0.771 \tag{3}$$

2.2. Simulation Results and Analysis

The current loop simulation model is shown in Figure 1.

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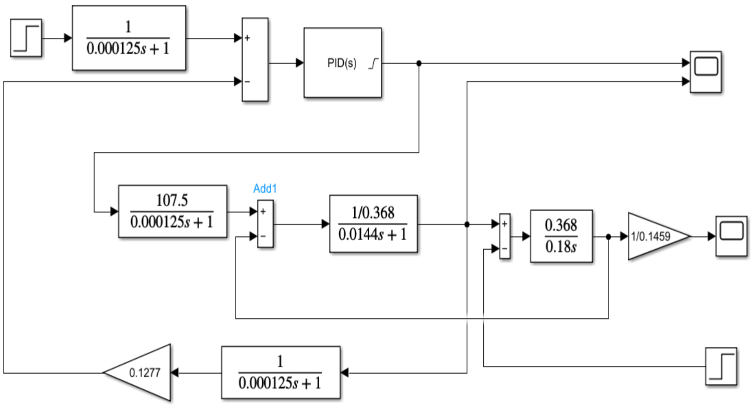

Figure 1: The current loop simulation model.

When KT is 0.5, the waveform of the armature current and voltage are shown in Figure 2 and 3.

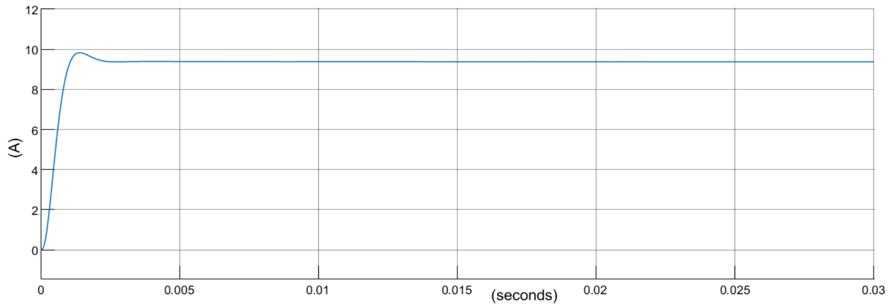

Figure 2: The waveform of the armature current.

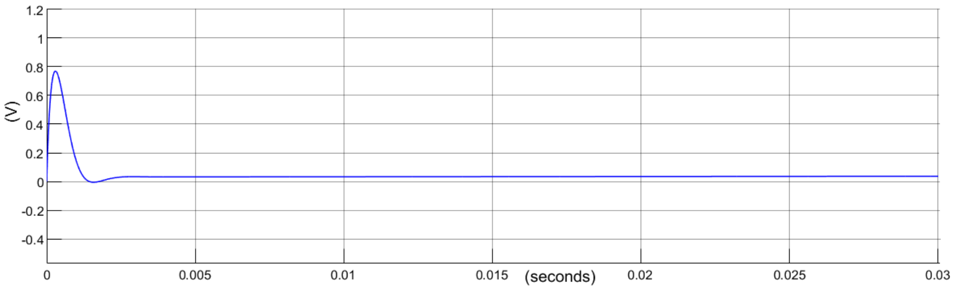

Figure 3: The waveform of the armature voltage.

It can be seen from Figures 2 and 3 that when KT=0.5, the armature voltage rises rapidly at startup to quickly establish the armature current; as the armature current increases, the output of the voltage regulator decreases, and the armature voltage also drops quickly. Subsequently, to maintain a constant armature current, the armature voltage remains constant.

When KT is 0.25, the waveform of the armature current and voltage are shown in Figure 4 and 5.

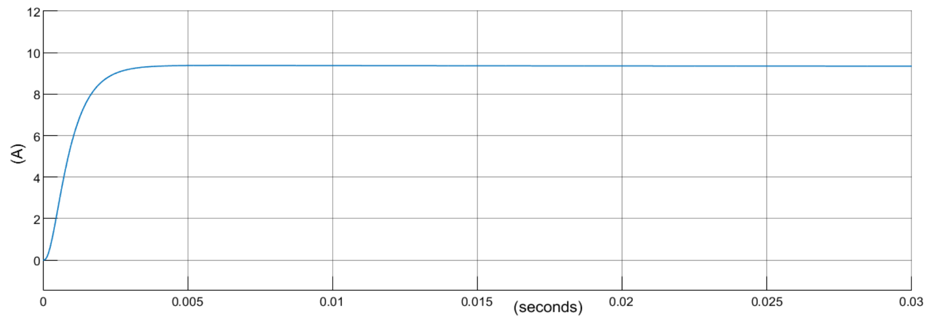

Figure 4: The waveform of the armature current.

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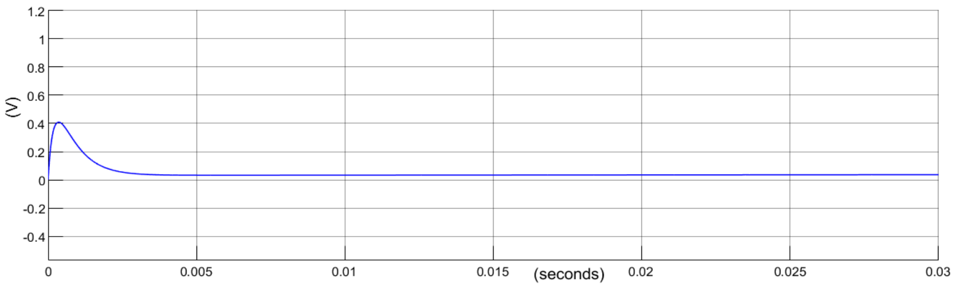

Figure 5: The waveform of the armature voltage.

As can be seen from Figures 4 and 5, when KT=0.25, there is no overshoot, but the rise time is long.

When KT is 1, the waveform of the armature current and voltage are shown in Figure 6 and 7.

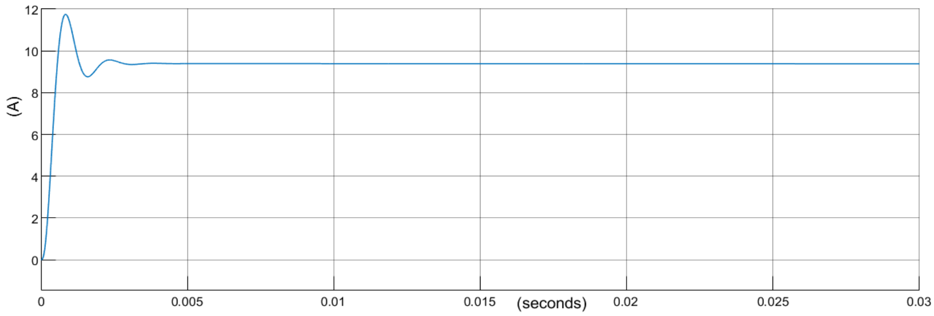

Figure 6: The waveform of the armature current.

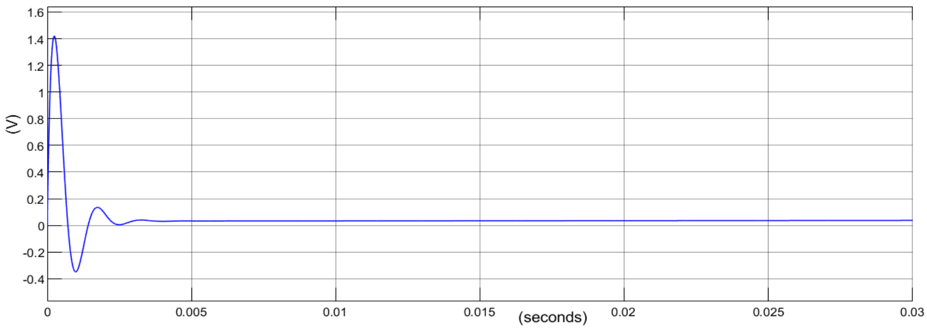

Figure 7: The waveform of the armature voltage.

It can be seen from Figures 6 and 7 that when KT=1.0, there is a large overshoot, but the rise time is short.

From the analysis of Figures 2 to 7, it can be seen that there is no steady-state error in the current loop. This is because the current setpoint is very small, the motor cannot start, and the current loop is not disturbed by the motor's counter electromotive force, so the system has no steady-state error.

3. Teaching Effect Analysis

3.1. Good Teaching Results

Firstly, the author uses the results of the simulation system to analyze and explain the working principles of the closed-loop control system, enabling students to have a more intuitive understanding of the system's working principles. Secondly, the parameters of the current regulator and speed regulator designed using the engineering design method can be directly verified for their rationality through the simulation system. This allows students not only to have a better understanding of the importance of regulator parameter design in theory but also to understand the impact of parameters on the system's responsiveness and stability in practical engineering. Finally, the focus and difficulties in teaching are overcome by combining simulation results with theoretical calculation results.

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3.2. Students Are Proactive and Active

After incorporating the simulation segment, the most obvious change is the enhancement of students' self-directed learning. Students can gain an intuitive understanding of every part of the system through the simulation establishment process. For example, the effects of proportional regulators and proportional-integral regulators on the speed control system's results were previously only on paper. Now, with the addition of simulation, students can directly observe the differences between proportional regulators and proportional-integral regulators through the results, and even more, they can discern the differences between speed control systems with and without steady-state errors through the simulation outcomes.

4. Conclusions

During the teaching process of the "Electric Drive Automatic Control Systems" course, by introducing intuitive simulation teaching, students have gained a deeper understanding of electric drive automatic control systems. They have a profound comprehension of the abstract and difficult professional theoretical analysis, not only verifying the conclusions from textbooks but also mastering the impact of changes in parameters or links on the operation of the control system. Additionally, students can perform more complex system analysis, which enhances their interest in learning, and can change the dilemma faced by the course in previous teaching that is detached from reality. Through teaching practice, it has been proven that introducing simulation teaching methods in the teaching process has achieved good teaching results, which greatly helps in cultivating students' thinking abilities and practical hands-on skills.

Acknowledgements

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