УДК 00 – 621.314

Боиханов З.У.

Доцент (PhD)

Аъзамов С.С.

(PhD)

Андижанский государственный технический институт

ИССЛЕДОВАНИЕ МЕТОДА ПОВЫШЕНИЯ ТОЧНОСТИ УПРАВЛЕНИЯ ЭЛЕКТРОПРИВОДОМ СЕРВОДВИГАТЕЛЯ И СИГНАЛА УПРАВЛЕНИЯ

Аннотация: В мире проводится ряд научных и практических исследований, направленных на обеспечение качественных и бесперебойных режимов работы электромеханических систем без чрезмерных потерь. В статье системно рассматриваются проблемы повышения точности сигналов управления сервоприводами электромеханических систем. Проанализировано взаимодействие систем обратной связи, энкодеров, цифровых фильтров, алгоритмов формирования ШИМ-сигналов и механизмов ПИД-регулирования в сервоприводах, требующих высокого быстродействия и точности, особенно в современных системах промышленной автоматизации. В статье подробно рассматриваются математическое моделирование, алгоритмическая оптимизация, работа элементов АЦП/ЦАП и технологии цифровой фильтрации для снижения уровня шума, необходимые для точной передачи и преобразования сигнала. В статье также предлагаются следующие технологические решения: использование высокоточных энкодеров прямоугольных импульсов, модифицированных типов ПИД-алгоритмов (ПИ-Д, И-ПД), адаптивных систем обратной связи, а также использование технологий DSP (цифровой сигнальный процессор) и FPGA для мониторинга сигналов в реальном времени. Результаты исследований показывают, что использование этих подходов позволяет увеличить скорость отклика сервосистемы, снизить неопределенность и добиться высокоточного позиционирования.

Ключевые слова: серводвигатель, управляющий сигнал, точность сигнала, ШИМ (широтно-импульсная модуляция), энкодер, ПИД-регулирование, адаптивная обратная связь, цифровой фильтр, микроконтроллер, DSP, FPGA, позиционирование, фильтрация шумов, моделирование.

Boihanov Z.U.

Associate Professor (PhD)

Azamov S.S.

(PhD)

Andijan State Technical Institute

RESEARCH ON A METHOD FOR INCREASING THE ACCURACY OF SERVOMOTOR ELECTRICAL DRIVE CONTROL AND CONTROL SIGNAL.

Abstract: A number of scientific and practical research works are being carried out in the world to provide electromechanical systems with high-quality and uninterrupted, as well as high-quality operating modes without excessive losses. The article systematically considers the problems of increasing the accuracy of control signals in servomotor devices in electromechanical systems. In particular, the interaction of feedback systems, encoders, digital filters, PWM signal shaping algorithms and PID control mechanisms in servo control units requiring high speed and accuracy in modern industrial automation systems is analyzed. This article extensively covers the mathematical modeling, algorithmic optimization, operation of ADC/DAC elements, and digital filtering technologies that reduce noise necessary for accurate signal transmission and conversion. The article also proposes the following technological solutions: the use of high-precision square pulse encoders, modified types of PID algorithms (PI-D, I-PD), adaptive feedback systems, the use of DSP (Digital Signal Processor) and FPGA technologies for real-time signal monitoring. The results of the study show that using these approaches, it is possible to increase the response speed of the servo system, reduce uncertainties, and achieve high-precision positioning.

Keywords: Servomotor, control signal, signal accuracy, PWM (pulse-width modulation), encoder, PID control, adaptive feedback, digital filter, microcontroller, DSP, FPGA, positioning, noise filtering, modeling.

Introduction: Servomotor devices are an indispensable component of modern automated systems, which are widely used in high-precision positioning, speed and torque control. Especially with the development of digital control systems, the accuracy of the control signal transmitted by servomotors directly determines the quality and stability of technological processes. This article scientifically analyzes the formation of control signals in servomotors, transmission, reception, feedback, protection mechanisms against noise and distortion, methods for increasing accuracy, modeling and practical software solutions. The structure of the servomotor control system, The servomotor system is mainly composed of the following elements: Programmable controller (controller or microcontroller), signal amplifier (servo amplifier), motor (AC or DC type), encoder or resolver (feedback sensors), sensors and filters, algorithmic control module. This system operates in real time. The PWM (Pulse Width Modulation) signal output from the signal generator (microcontroller or PLC) controls the motor through the servo amplifier. At the same time, the encoder retransmits the motor state, and the controller controls it. Factors affecting the accuracy of the control signal The main factors determining accuracy are: the frequency and pulse duration of the PWM signal, the encoder resolution (number of bits), the accuracy of the analog-to-digital (ADC) and digital-to-analog (DAC) converter, noise (electromagnetic, thermal, digital interference, frequency resonance conditions, variable loading and inertia. Each component can distort the signal or introduce uncertainty. For example, a low-precision encoder may not be able to detect a 1-degree displacement, which will lead to defective movement in the robot manipulator. Encoders and their role. Encoders are the main element of servomotor feedback. They are divided into: Incremental encoder (counts based on steps), absolute encoder (gives a unique code for each position) Optical, magnetic, inductive type encoders. Absolute encoders are characterized by high accuracy and reliability. A 19-bit absolute encoder can detect 524,288 positions. This is very means high accuracy.

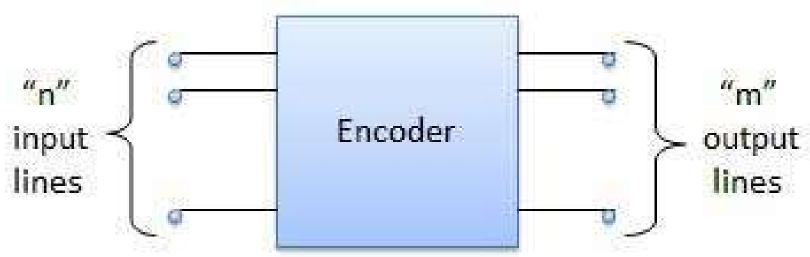

Figure 1 Block diagram of encoders.

Pwm signal shape and its analysis. The accuracy of a PWM signal depends on its frequency and pulse duration. For example:

1.000 ms → 0°

1.500 ms → 90°

2.000 ms → 180°

However, if the signal is interfered with by noise or interruption, the motor may stop at the wrong angle. Therefore, it is necessary to clean the signal through filters and stabilize the PWM pulse.

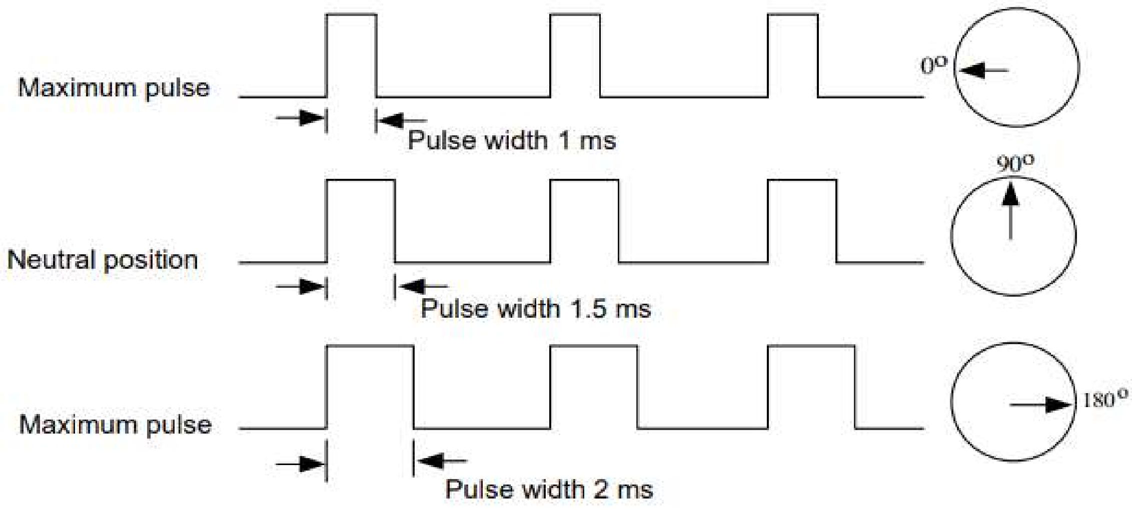

Figure 2 PWM signal graph

Anti-noise filtering methods are divided into: RC low-pass filters, digital median filtering, Kalman filter, soft filter based on the average value. Filtering increases accuracy by maintaining the purity of the control signal and eliminating fluctuations in the pulses.

PID and digital control algorithms. The most widely used algorithm in servomotor control is PID (Proportional-Integral-Derivative). This algorithm: detects position errors, adjusts speed and direction, and provides continuous optimization. The PID algorithm is based on real-time data. At the same time, approaches such as Fuzzy Logic, LQR, Sliding Mode Control are also used in modern systems.

Figure 3 control signal sequence

Signal conversion: adc and dac, analog-to-digital (ADC) and digital-to-analog (DAC) converters are the link between the controller and the motor. Their resolution and sample rate play an important role in ensuring accuracy.

8-bit ADC → 256 levels

12-bit ADC → 4096 levels

16-bit ADC → 65536 levels

If the signal received by the converters is noisy, the control obtained from it will be incorrect. Therefore, for their stable operation, the power supply and signal lines must be protected.

Servo amplifiers. Servo amplifiers convert the PWM signal into the required power and current. They: can be analog or digital, control the current limit, operate with feedback. Their internal circuit is based on MOSFET or IGBT transistors.

Inertia and load balance The inertia and center of gravity of the mechanical load connected to the servomotor shaft affect the control accuracy. High inertia loads cause control lag. Dynamic loads change the impulse. Therefore, PID settings are adjusted depending on the load inertia. Sensor integration Servo systems are integrated with the following sensors: Temperature sensors (thermistor), current sensors (hall effect), speed sensors, position sensors (optical, magnetic). Data processing, The data received from the sensors goes through the following stages in real time: Signal reception, filtering, scaling (conversion to a unit of measurement), adjustment and compensation, transmission to the control algorithm, balance between energy efficiency and accuracy. nHigh-precision control requires more computing power and energy consumption. Therefore: It is necessary to optimize signal processing, reduce harmful outputs, use active cooling systems.

Software. Microcontrollers for servomotor systems: STM32, Arduino (with extended modules), TI C2000, Raspberry Pi (for complex systems) Software environments: C/C++, Simulink, LabVIEW, FreeRTOS (real-time OS) problems and their elimination. To solve the problems and their elimination, the following steps should be taken:

Signal interference → shielded cables.

Uncertain position → encoder replacement.

Delay → algorithm optimization.

System heating → cooling system.

Conclusion: In servomotor electric drive systems, the high efficiency and accurate and reliable operation of the device is generally related to the accuracy and reliability of the control signal system, and these indicators are the main factors determining the efficiency and accuracy of the servomotor. In this article, all technical, software and physical factors affecting the accuracy of the control signal were scientifically analyzed. To increase accuracy, it is necessary to comprehensively apply modern signal filtering, high-precision sensors, digital control algorithms, modeling and real-time monitoring technologies. The relevance and solution methods for conducting future scientific research in the areas of automatic calibration, optimal PID tuning, noise compensation, and system prediction using artificial intelligence algorithms are presented.

References

1. Mirzoev N., Azamov S. Control and management of active and reactive power balance in a solar power supply system //Международный научный журнал «Инженер». – 2025. – Т. 3. – №. 1. – С. 39-44.

2. Siddikov I., Azamov S., Berdiyev D. RESERCH OF REACTIVE POWER CONSUMPTION OF SINGLE-PHASES ASYNCHRONOUS MOTOR ENERGY SUPPLIED BY SOLAR PANELS (DEBSEUZ PROJECT ACTIVITY) //PERSPECTIVES OF HIGHER EDUCATION DEVELOPMENT. – 2024. – Т. 15. – №. 1. – С. 89-95.

3. Siddikov I. X., Denmuxammadiyev A. M., A'zamov S. S. MUQOBIL TURDAN OLINGAN ENERGIYADAN ISTEMOL QILUVCHI ASINXRON MOTOR QUVVAT BALANSINI NAZORAT VA MONITORING QILISH //JIZPI XABARNOMASI. – 2024. – Т. 1. – №. 1. – С. 126-128.

4. Saidmurodovich A. S. The Prospects Of The Construction Of Hydroelectric Power Plants In Uzbekistan And The Issues Of Increasing Their Number And Widespread Use //The American Journal of Engineering and Technology. – 2020. – Т. 2. – №. 11. – С. 118-121.

5. Siddikov I. et al. ANALYSIS OF POWER DISSIPATION IN A TRIANGLE CONNECTION OF SINGLE-PHASE ASYNCHRONOUS MOTOR SUPPLIED FROM SOLAR ENERGY SOURCE //Science and innovation. – 2023. – Т. 2. – №. A11. – С. 14-18.

6. Аъзамов С. С. УЛУЧШЕНИЕ МЕХАНИЧЕСКОЙ ПРОЧНОСТИ ЭЛЕКТРИЧЕСКИХ ПРОВОДОВ ВЫСОКОГО НАПРЯЖЕНИЯ //Universum: технические науки. – 2021. – №. 5-5. – С. 47-49.

7. Mirzoyev N.N., Sayfiyev O.H., Temirov T.O. Investigation of unauthorized connection to electrical networks, failure to detect their phase

interruptions and short circuits to ground, ResearchJet Journal of Analysis and Inventions 3 (10), 130-143 (2022)

8. Azamov S. et al. ANALYSIS OF ELECTRICAL AND MECHANICAL CONDITION MONITORING OF ASYNCHRONOUS MOTOR SUPPLIED FROM SOLAR PANEL ENERGY SOURCE //Conference on Digital Innovation:" Modern Problems and Solutions". – 2023.elektr ta'minoti tizimini loyihalash. Pedagogs jurnali 10 (1), 2022/6/11, 100-108 bet

9. I.X. Siddikov, N.N. Mirzoyev, M.A. Anarboev, S.I. Davrboeva. Izolyatsiya holatini monitoring qilish va elektr tarmoqlariga ruxsatsiz ulanishlarni aniqlash uchun kompyterlashgan axborot o 'lchov tizimiming istiqbollari, "Raqamli energetika tizimini yaratishning istiqbollari, muqobil energiya olishning muammolari va yechimlari-2023" xalqaro ilmiy-amaliy konferensiyasining ilmiy maqola va tezislari to'plami. Jizzax, 2023 yil 19-20 may, 252-257bet.

10. Аъзамов С. С. УЛУЧШЕНИЕ МЕХАНИЧЕСКОЙ ПРОЧНОСТИ ЭЛЕКТРИЧЕСКИХ ПРОВОДОВ ВЫСОКОГО НАПРЯЖЕНИЯ //Universum: технические науки. – 2021. – №. 5-5. – С. 47-49.