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EMPLOYING A PID CONTROLLER AND AN INFORMATION AND MEASUREMENT COMPLEX FOR RELIABLE ELECTRIC MOTOR MODELING AND PROGRAMMING

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Abstract. The research is focused on developing an algorithm of choice and use of different types of PID controllers, and the tuning of its settings to simulate the word and control the speed and position of a DC motor (direct current motor).After analyzing the characteristics of the DC motor and speed and position sensors of the system (typically an encoder) the researchers were able to ensure safe operating conditions and provide the experimenter with data about the limits of the motor, its capabilities and optimal working conditions. As equipment the QNET DCMCT DC motor control trainer was used. A step response test was conducted during the research to evaluate system stability based on its reaction to a step input signal. The Ziegler-Nichols method is recommended for controlling the position of a DC motor. This two-step tuning method involves performing a test to quantitatively assess the system's behavior in terms of how quickly and to what extent the process variable changes with alterations in the control input. The results of these tests are used in empirical formulas to determine appropriate controller settings for desired performance. The method involves determining the critical period Tu (ultimate period) and the critical gain Pu (Ku) (ultimate gain). The information and measurement complex with PID controller temporarily disables its algorithm, replacing it with an ON/OFF relay, causing the process variable to oscillate. These obtained values describe the process behavior to guide PID tuning for the desired closed-loop performance. The method involves determining the critical period Tu (ultimate period) and the critical gain Pu (Ku) (ultimate gain).

Keywords: information and measurement complex, metrology, measurement of physical quantities, PID algorithm, DC motor, error, stability, quality assessment.

Introduction

Control system commands directs and regulates the behavior of other devices using control loops.

Depending on the control method, automatic control systems can be classified as open-loop systems, closed-loop (feedback) systems, feedforward (also known as direct control) systems, and complex systems.

Statement of the article's objectives – use of a PID controller integrated into the information and measurement system for programming a DC motor.

Analysis of modern foreign and domestic research and publications

Article [1] describes the use of Simulink to implement the Proportional Integral Differential (PID) controller that can be used to control the speed of DC motor and bring it at the desired speed. Pulse width Modulation (PWM) is another technique which involves the use of the same simulation software. Hardware implementation requires the use of Infrared (IR) sensors and Arduino (open source platform for building Electronic project) for measuring the Rotations per minute (RPM) of the DC motor. Motor speed was measured using three techniques and a further comparison between these techniques is carried out according to the desired and control speed. The applications of our research could be in conveyors, turntables and others for which adjustable speed and constant or low-speed torque are required. It also works well in dynamic braking and reversing applications, which are common in many industrial machines.

Article [2] describes technique for controlling the speed of a DC motor using a PID controller, its construction, and the selection of PID parameters depending on the system response. A PID controller is used to control the speed of the DC motor, and the Matlab program is used for calculations and simulations. The parameter has been shown in several contrast experiments and explains how to adjust the value of the PID

Basic material

Let us consider a feedback control system.

Feedforward (direct) control systems rely on the disturbance signal and adjust the input control signal to counteract these disturbances. Unlike feedback control systems, feedforward structures no longer depend on measuring and adjusting the output. In other words, such systems are used in situations where disturbances can be accurately predicted and responded to in time.

Feedback control systems include a feedback loop that continuously monitors and regulates the output of a device. This loop makes adjustments to the process flow to achieve the desired result. The method involves input data, which initiates the process; the process itself, which is being controlled; output data, representing the result; a sensor that collects information about the process; a controller that issues commands; and an actuator that carries out those commands.

There are various types of feedback control systems, including positive and negative feedback.

In a positive feedback system, the controller adds the output values to the setpoints (desired values), aligning them with the input signals. This type of feedback can amplify or weaken the effect that caused the signal change, depending on clearly defined limits. In other words, a change (increase or decrease) in one variable eventually leads to a similar change (increase or decrease) in another variable. An example of this is a nuclear bomb explosion: the released plutonium neutrons trigger further fission events, increasing the number of neutrons and resulting in a chain reaction and explosion.

Negative feedback, on the other hand, subtracts the output signal value from the input (which is considered the desired result). The resulting difference is referred to as the error, indicating how much the output deviates from the desired input.

For continuous modulated control, a feedback controller is used to automatically manage a process or operation. The control system compares the value or state of the process variable (PV) being regulated with the desired or setpoint value (SP) and uses the difference as a control signal to bring the output variable of the installation's process to match the setpoint.

In general, there are several fundamental differences between feedforward and feedback control systems. Functionally, a modified feedforward system may include a feedback loop, but feedback control systems typically do not have a built-in feedforward mechanism. Moreover, a feedback system can detect all types of disturbances, unlike a feedforward system. Additionally, the latter has further limitations: it is not suitable for nonlinear, time-varying, or adaptive systems, whereas feedback control is more versatile. The most important aspect is that a feedforward system requires a highly skilled operator who can account for all process parameters and develop an optimal strategy to compensate for changes and errors in the device's operation, whereas using a feedback system generally only requires basic knowledge of how the control process flows.

A feedback controller that switches sharply between two states is used for on-off control. Such simple control systems can be inexpensive and effective. Below are a few examples of how these systems are used in household appliances.

A bimetallic thermostat consists of two metal strips that deform under the influence of temperature, thereby switching the electrical contacts in the thermostat. This works based on the principle of differing expansion coefficients of the two metals (for example, steel and copper).

A refrigerator also responds to temperature changes, but in a different way. When the temperature drops due to the door being opened or hot food being loaded, a sensor detects the change and sends the data to a control device (usually a controller or thermostat), activating the compressor until the set temperature is restored.

An electric motor is a device that converts electrical energy (in the form of voltage and current) into mechanical energy (either linear or more commonly – rotational motion). Electrical energy is supplied to the input of the motor, and mechanical energy is delivered at the output. From a black-box perspective, the motor produces mechanical motion from supplied electrical energy. This is made possible by the phenomenon of electromagnetism.

If we delve into the operating principle, we find a fairly simple system. When electric current flows through the rotor windings, it creates a magnetic field. This magnetic field interacts with the magnetic field of the stator (which can be generated using either electromagnets or permanent magnets). The interaction between the stator and rotor fields produces a torque that causes the rotor to rotate. The commutator reverses the direction of the current in the rotor windings with each half-turn to ensure continuous rotation in one direction. The rotation of the rotor is transmitted to the shaft, which in turn performs mechanical work.

Typically, a control system consists of the following components:

Drive (such as a motor) and its control board;

Sensor (for speed, torque, position, etc.);

Microcontroller board.

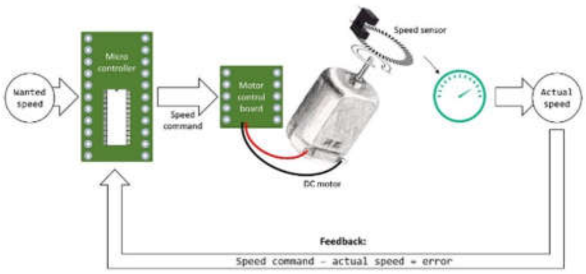

Figure 1 – Work model of control system

There are various ways to control a direct current (DC) motor. Speed and position control are the two most common examples, but torque control is also possible. If desired, it's even possible to monitor and control parameters like temperature or noise level. Naturally, each control method requires a corresponding sensor– for example, a speed controller works effectively with a speed sensor.

The term PID stands for Proportional, Integral, Derivative. These are the three main components of the control algorithm, each associated with a respective constant. These components are calculated based on the error provided by the sensor.

$$Command_{PID} = f_P(e) + f_I(e) + f_D(e) . \quad (1)$$

There is specific terminology involved here:

Setpoint (command variable, desired value) is the target value that the actuator should reach.

Process variable is the actual value measured by the sensor during the operation.

Error is the difference between the setpoint and the process variable.

Steady (stable) state is the condition in which the system stops oscillating and reaches full balance.

Proportional component

When there's a need to reach a specific value, a P-controller can handle this task. The proportional (P) component is always used in PID control. P, PI, PD, and PID represent the four possible combinations of control loops.

In the first control cycle, the controller does not operate – all coefficients are zero, and the error ranges from zero to the value of the setpoint. In the second cycle, the coefficients are equal to the error from the first cycle, and the output power gradually increases, reducing the error. In the third cycle, the coefficients respond to the second cycle's error, but the power increases too rapidly, causing an overshoot. In the fourth cycle, the coefficients respond to the resulting negative error from the previous overshoot, and the output power decreases, bringing the system closer to the desired value.

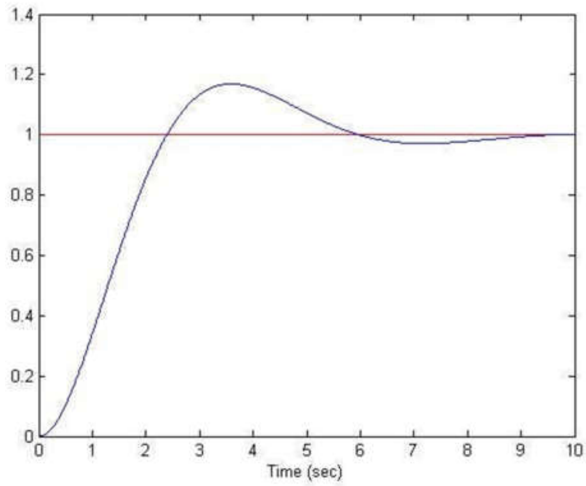

Figure 2 – Change in output power bringing the system closer to the desired value

The coefficient K_P is the value multiplied by the error. This means that the larger the error, the larger the corrective command. Mathematically, it is expressed as:

$$f_P(e) = K_P \times e . \quad (2)$$

In the case of a DC motor, using K_P is only suitable when controlling the rotor's (or screw's) rotational speed. That is, if the system needs to reach a certain value just once, then using the proportional part is sufficient. The problem arises when this value needs to be maintained.

There is a drawback to using only the proportional part: a certain offset in the steady state. When using only the proportional component of the PID, i.e., when I and D are equal to zero, a constant difference between the setpoint and the process variable appears in the steady state. This is called static error or steady-state error. This static error exists because the more loops there are, the closer the system gets to the setpoint, and the smaller the error becomes. However, when the error approaches zero, the system lacks the power to actually reach the setpoint.

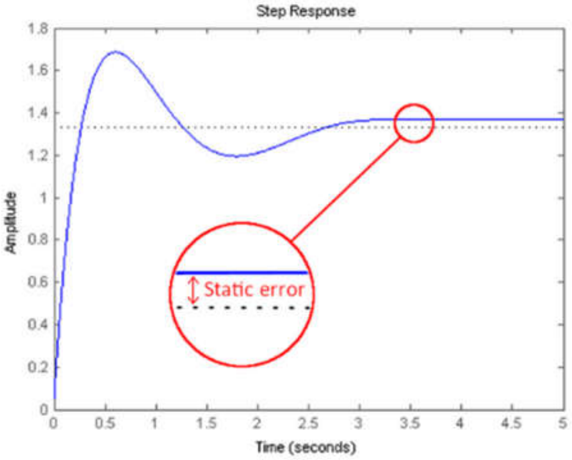

Figure 3 – The appearance of the static error

Integral parameter

Unlike the proportional part of the PID, the integral component cannot be used on its own because it will have no effect. Instead, the integral is either used with the proportional part (PI) or with both proportional and derivative parts (PID). In this case, the error is no longer treated as a variable but as a function of time, denoted as ε(t).[5]

I-only controllers have a much slower response time compared to P-only controllers because they depend on more parameters. If it is important to avoid offset in the system, then an I-only controller should be used, but this will require a slower response time.

To integrate ε(t), all previous values of the error function must be added. This is similar to summing all the small rectangles under the error curve when calculating the integral. The total sum is then multiplied by a constant, K_I, which controls the power of the integral part.

The key advantage of adding I-control to your controller is that it eliminates offset. The drawbacks are that it can destabilize the controller, and there is integrator windup, which increases the time required for the controller to make adjustments.[6]

A variable, such as sum_e, needs to be declared to accumulate each new error value ε(t) in each system cycle, something like sum_e+=e, and then it is multiplied by the K_I constant in the control function. This looks like:

$$f_I(e) = K_I \times sum\_e \quad . \qquad (3)$$

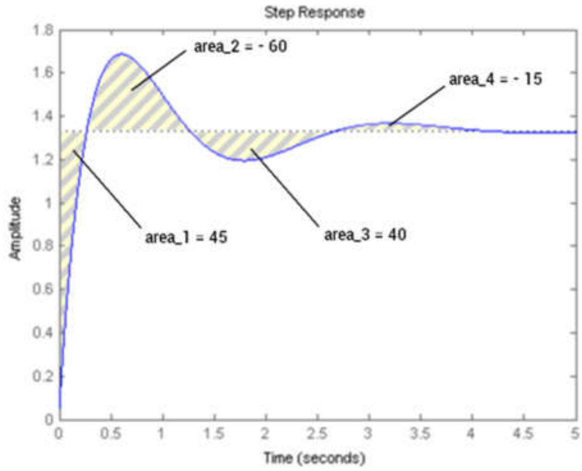

Figure 4 – Change in time required for the controller to make adjustments [6]

Adding the integral command will correct the static error caused by using only the proportional control set. Indeed, as long as there is an error, i.e., ε(t)≠0, even if ε(t) is small compared to the initial error, it will still affect the system due to its residual value, preventing the proportional part from reaching the desired outcome.

Derivative Parameter

Unlike the proportional part of PID, the derivative part, like the integral part, cannot be used independently as it will have no effect. Instead, the derivative is either used with the proportional part (PD) or with both proportional and integral parts (full PID).

The letter D stands for derivative, as it differentiates the calculated error in the PID command.

The derivative of a function is the result of differentiating that function.

Let's take a continuous function y=f(x). f is a function that transforms x into y.

Now, let's call f'(x) the derivative of f(x). f(x) has been differentiated to give f'(x).

Mathematically, the derivative f″ of f is the ratio of the change in the output value to an infinitesimal change in the input value. Limits are used to demonstrate this change in input data.

Differentiation of a function is similar to measuring how much the output y changes when we change the input x. The control output is calculated based on the rate of change of the error over time. The faster the rate of change of the error, the more pronounced the controller's response will be.

This tangent is the slope, and the slope is usually calculated for two points by dividing the difference in the y-axes by the difference in the x-axes of these points. In this case, it is assumed that these two points are very close to each other to make the slope as accurate as possible [7].

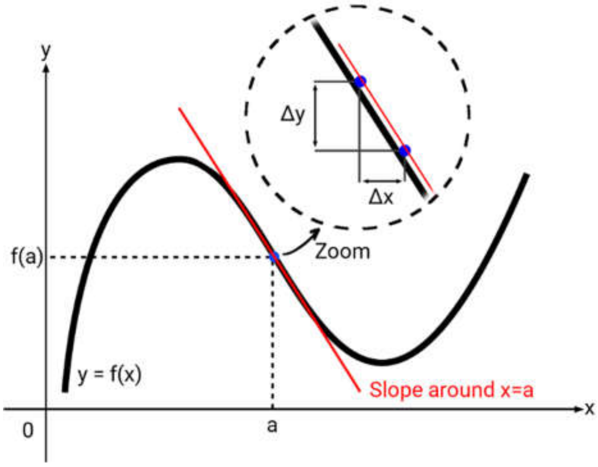

Figure 5 – Simulation of the tilt angle tangent during acceleration [7]

Thus, it can be remembered that the derivative of a function at point aa is the slope of the curve at that point.

If the position function of an object relative to time is differentiated, we get the velocity of the object. Why? Because velocity is the change in position: the more the position changes, the greater the velocity of the object. If the velocity function of the object is differentiated relative to time, the result is its acceleration.

Therefore, the derivative has a "predictive" effect, showing what the error will be by obtaining the magnitude of its variation in order to reduce it. The derivative smooths (dampens) oscillations, i.e., it reduces the intensity of the system's response, making it more stable. This improves the quality and stability of the motor's operation, which is applied in industrial production, household appliances, etc.

An important point: using the derivative works well for errors that show low dynamic changes. For example, measuring and controlling temperature is not prone to rapid changes. However, if the measured and controlled quantity undergoes very high dynamic changes or if the error is accompanied by strong noise, differentiating it can lead to even greater amplitude than the desired signal, which will cause the system to behave unstably.

Like I-control, D-control is mathematically more complex than P-control. Since a computer algorithm will take more time to compute the derivative or integral than to simply linearly relate input and output variables, adding D-control slows down the controller's response time.

To add the derivative expression $f_D(e)$ to the command, differentiation can be simplified by subtracting the previous cycle's error from the current cycle's error and multiplying this difference by the coefficient KD (the derivative gain).

$$f_D(e) = K_D \times (e - previous\_e) \tag{4}$$

Thus, the final form of the complete PID command will be:

$$\begin{aligned} Command_{PID} &= K_P \times e + K_I \times sum_e + \\ &+ K_D \times (e - previous\_e) \end{aligned} \tag{5}$$

From this, we can conclude that the proportional coefficient is based on the current error, the integral is based on errors from previous cycles, and the derivative anticipates future errors.

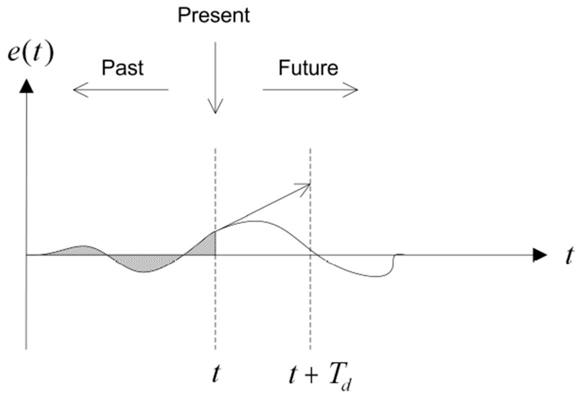

Figure 6 – Errors from previous cycles, and the anticipation of future errors

There are 3 types of control for DC motors: position control, speed control, and modeling. Generally, for new systems, it is common to begin by configuring and studying the basic characteristics of the motor through a bump test.

Bumpt test (modeling)

At the beginning of the process, it is necessary to familiarize yourself with the characteristics of the DC motor and system sensors. This ensures safe operating conditions and provides the experimenter with certain knowledge about the motor's limitations, capabilities, and the ability to calculate optimal working conditions.

A bump test is a simple check based on the step response of a stable system. A step signal is applied to the input, and the resulting output signal of the system is recorded.

Amplitude is the maximum deviation of a quantity during oscillatory or wave-like motion, which periodically changes from some value considered zero (or average) or from the equilibrium state of the system. As the amplitude increases, the intensity of the signal intensifies. In control systems, a stronger input signal results in a stronger system response. Conversely, decreasing the amplitude weakens the signal, leading to weaker system responses.

Frequency is a physical quantity equal to the number of identical events (or full cycles) per unit of time. Essentially, frequency regulates how quickly the signal oscillates. When frequency increases, the signal oscillates faster, which results in a quicker change in the input signal and a potential delay in the system's response if the system's reaction time is slower. Conversely, a lower frequency causes slower oscillations, giving the system more time to adapt to changes. This is beneficial for the stable operation of the system, but it also reduces the overall system efficiency.

Offset is a constant value added to the entire signal, shifting it vertically along the ordinate axis. It reflects a certain average value around which the signal oscillates. With a positive offset, the signal shifts upwards, increasing the base level of the signal, and with a negative offset, the opposite effect occurs.

The change of each of these parameters requires a careful and controlled approach. Adjusting one value often requires fine-tuning others to maintain the normal operation of the system. For example, increasing amplitude and frequency results in a stronger and more dynamic signal, which improves the system's working efficiency or reveals nonlinearity in its operation. Simultaneously increasing amplitude and offset raises the average working point and the intensity of the system's quality response, directly affecting the stability and saturation of the system components. Adjusting frequency and offset changes the working range and response time, requiring precise tuning to maintain the desired operating state of the system.

The input signal starts at time t_0, and from the graph, one can find the minimum (u_{min}) and maximum (u_{max}) values of the input voltage. The output (resulting) initial signal is at the level y0. After the step input signal is applied, the output follows it, eventually stabilizing at a steady-state value y_{ss}. From this, the steady-state gain coefficient K is calculated through the difference between the steady-state values of the input Δ_u and output Δ_y signals:

$$K = \frac{\Delta y}{\Delta u} = \frac{y_{ss} - y_0}{u_{max} - u_{min}} \qquad (6)$$

Speed Control

For controlling the speed of a DC motor, the use of a PI controller, that is, only its

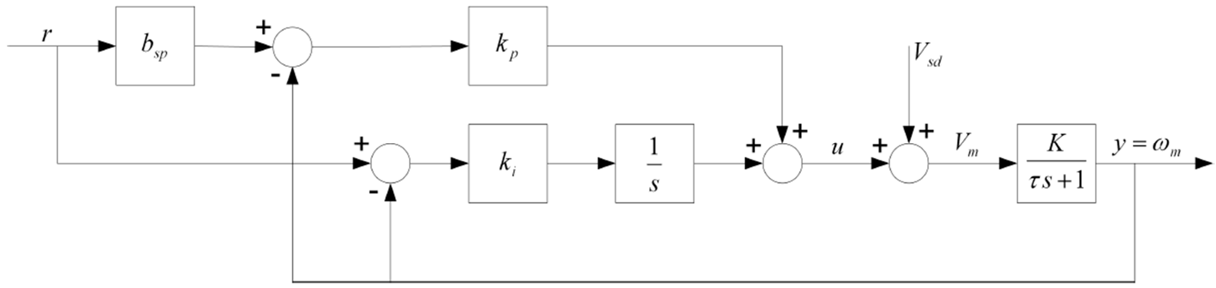

Figure 7 – Structural scheme of motor speed control

proportional and integral components, is sufficient.

From the known parameters, the maximum peak overshoot (PO), damping ratio (ζ), natural frequency of the closed-loop system (ω_0, also the undamped natural frequency $\omega_n = \omega_0$), and the gain coefficients k_p and k_i can be calculated. These gain coefficients, determined using the above parameters, are used to measure and control the rotational speed of the DC motor rotor, ensuring stability and constant adjustment of errors arising during operation, as well as errors caused by internal or external influences.

If the damping ratio ζ is not provided in the motor's initial parameters, it can be calculated using the formula for the peak overshoot of the system (PO). The overshoot formula is:

$$PO = 100 \cdot e^{\frac{-\varsigma\pi}{\sqrt{1-\varsigma^2}}} \tag{7}$$

Solving for ζ from the original formula above gives the following dependency:

$$\varsigma = \frac{-\ln(\frac{PO}{100})}{\sqrt{\pi^2 + (\ln(\frac{PO}{100}))^2}} \tag{8}$$

The undamped natural frequency ω_n can be found using the model time constant τ. The formula for the dependency is:

$$\tau = \frac{1}{\varsigma\omega_n} \tag{9}$$

From this, ω_n can easily be calculated as:

$$\omega_n = \frac{1}{\varsigma\tau} \tag{10}$$

Knowing this, the next step is to calculate the coefficients:

$$k_p = \frac{-1 + 2\varsigma\omega_0\tau}{K} \tag{11}$$

and

$$k_i = \frac{\omega_0^2\tau}{K} \tag{12}$$

Large values of ω_0 lead to high controller gain values. The damping ratio ζ and the parameter for weighting the setpoint value b_{sp} are used to adjust the speed and peak overshoot of the response to command variables.

The setpoint value parameter b_{sp} is typically specified within the range of 0 to 1, where 0 provides a smooth increase or decrease in the signal, while 1 increases the system's response speed.

In a controller using SPW, the proportional function acts only on a fraction b_{sp} of the command value, and there is no derivative of that same value. The integral function continues to influence the total error to ensure that the error approaches zero in steady-state. Standard PID controllers and PID controllers with setpoint weighting respond to disturbances in the same way, but their responses to setpoint changes differ.

Disturbing and controlling influences are distinguished. Disturbing influences are random in nature and difficult to predict. For example, changes in ambient temperature or fluctuations in voltage in the power grid. The controlling influence on the controlled object is organized via a control device or an operator, with the goal of compensating for the effects of disturbing actions.

Position control

For position control, the Ziegler-Nichols method is recommended. This is a two-step tuning method, which involves conducting a special test to quantitatively assess the process behavior in terms of how fast and to what extent the process variable changes when the control input (setpoint) is altered. Based on this, they developed a set of empirical formulas to convert the results of these tests into corresponding performance settings and control parameters for the controller.

The essence of the method lies in determining the ultimate period T_u (ultimate period) and the ultimate gain coefficient P_u (K_u) (ultimate gain). During this, the controller temporarily disables its PID algorithm and replaces it with an ON/OFF relay, which forces the process variable to oscillate. These values well describe the process behavior, helping to determine how the PID controller should be tuned to enhance the closed-loop performance and improve the quality of the process itself.

The amount by which the process variable changes over time and the time required for it to reach 63.2% of its final (highest stable) value indicate the process gain in steady-state and the time constant of the process, respectively. If the sensor in the loop is located a certain distance from the actuator, the process response to such a step change may also show the delay time between when the step was applied and when the process variable first started to respond.

The time required to complete one oscillation is called the critical period T_u, and the relative amplitude of two oscillations, multiplied by 4/π, gives the critical gain coefficient P_u (K_u). Ziegler and Nichols theoretically assumed that these two parameters could be used instead of the steady-state gain, time constant, and dead time to calculate the corresponding tuning parameters using their well-known equations or tuning rules.

Empirically, they found that these rules generally produce a controller that responds quickly to intentional setpoint changes, as well as random disturbances of the process variable. However, a controller tuned this way tends to overcorrect and oscillate the process variable, which is why most self-tuning controllers offer several alternative tuning rules that make the controller behavior more stable (less aggressive). In practical terms, the operator typically only needs to choose the desired response speed (slow, medium, fast), and the controller automatically selects the appropriate tuning rules to meet the request.

A controller can be made more or less aggressive by adjusting three tuning parameters – the proportional gain K_p, the integral time T_i, and the derivative time T_d. The Ziegler-Nichols tuning rules can be used to calculate moderately aggressive tuning values based on the critical period T_u and the critical gain coefficient P_u (K_u).

During the experiment, the integral and derivative (differential) gains are set to zero, while the proportional gain is manually increased until the system starts oscillating with a constant amplitude. The critical gain at which the system begins to oscillate is recorded, and the integral and derivative gains are then adjusted according to a set of rules and formulas to achieve the optimal tuning.

For position control of a DC motor, it is typically sufficient to use only the PD-controller components, without relying on the integral component.

In this case, the proportional and derivative gains can be calculated as:

$$k_p = \frac{\omega^2_0 \tau}{K} \tag{13}$$

And

$$k_d = \frac{-1 + 2\varsigma\omega_0\tau}{K} \tag{14}$$

If the integral part is added to handle random disturbances and steady-state errors, the calculations become:

For K_p:

$$k_p = \frac{\omega_0\tau + (\omega_0 + 2\varsigma p_0)}{K} \tag{15}$$

For K_d:

$$k_d = \frac{-1 + 2\varsigma\omega_0\tau + p_0\tau}{K} \tag{16}$$

For K_i:

$$k_i = \frac{\omega_0^{\ 2} p_0 \tau}{K} \tag{17}$$

Work in this area is relevant and was particularly in demand by the companies PC "Ivano-Frankivskcement." This research was carried out by a student of the educational and professional program "Metrology and Information-Measuring Technology" as part of an industrial internship. The research results were also presented at the All-Ukrainian Scientific and Pedagogical Forum "Innovative Technologies in Education" in 20.10.2024.

A competition project on this topic, prepared by Herman Krovopuskov, won a prize at the «Челендж інтелектуальний вимір 2024 "InnoVative Technologies" (IVT_2024)» held on 08.05.2025.

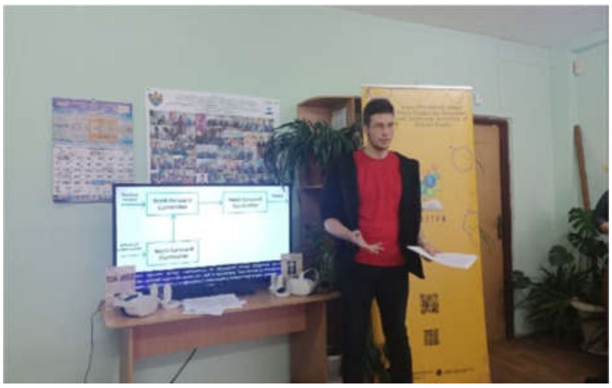

Figure 8 – Approbation of the research «InnoVative Technologies»

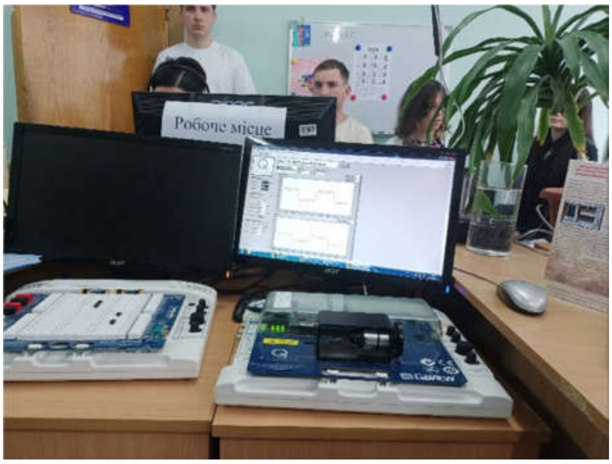

Figure 9 – Practical use of the research study with the use of information and measurement complex

It is worth noting that such cooperation between the University and specialized companies is a key factor in the successful employment of graduates of the G6 specialty «Information and Measurement Technologies».

Thus, the measurement of physical quantities and their metrological research; testing the stability and reliability of systems and information-measuring complexes; studying the quality of engine control systems, which are widely used in household appliances such as washing machines, vacuum cleaners, air conditioners, etc., where a precise and reliable electric motor control system is required. Due to their simplicity and efficiency, PID controllers help improve energy efficiency, reduce wear of mechanical components, and enhance user experience by ensuring stable and quiet operation of devices. Therefore, such research and its practical implementation are optimally integrated into the employment opportunities of our graduates, particularly in terms of expanding their scope to include service processes and industry represented in Ukraine's national economy.

The scientific novelty lies in the combination of the Ziegler-Nichols method with a weighted setpoint parameter, bsp. This combination made it possible not only to significantly reduce the calculation time compared to the classical calculation method, but also to provide the user with the ability to adjust the system's response speed to their own needs – even without possessing all the necessary technical knowledge by allowing control through the modification of a single parameter. This would be convenient for use in everyday household appliances, such as a hair dryer - this functionality would allow devices to operate properly for a longer time and simplify the control of output power at the user's discretion.

Conclusions

In the course of this study, the effectiveness of a PID controller in regulating the speed of a direct current (DC) electric motor was thoroughly evaluated. The results indicate that the implementation of PID control ensures high precision in maintaining the target rotational speed of the motor shaft, even under variable load conditions and external disturbances. Experimental data confirm that the controller successfully mitigates dynamic deviations, contributing to stable and consistent motor operation with minimal oscillation or delay. Furthermore, the findings underscore the importance of accurate tuning of the proportional, integral, and derivative parameters, as well as the distinct influence each has on system performance. Proper parameter optimization was shown to be essential in achieving the desired control behavior.

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Conflict of interest
None.

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ВИКОРИСТАННЯ ПІД-РЕГУЛЯТОРА ТА ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНОГО КОМПЛЕКСУ ДЛЯ НАДІЙНОГО МОДЕЛЮВАННЯ Й ПРОГРАМУВАННЯ ЕЛЕКТРОДВИГУНІВ

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Анотація. Робота присвячена розробленню алгоритму вибору та використання різновидів PID-контролера, а також налаштуванню його параметрів для моделювання роботи, контролю швидкості та положення DC-двигуна (двигуна постійного струму). Здійснивши аналіз характеристик двигуна постійного струму та датчиків швидкості і положення системи (найчастіше енкодера), отримано можливість забезпечити безпечні умови роботи та надати експериментатору інформацію про обмеження роботи двигуна, його можливості та розрахувати оптимальні умови роботи. В якості навчального обладнання використано тренажер контролю двигуна постійного струму QNET DCMCT. В процесі досліджень проведено ударний тест – перевірку на базі крокової реакції стабільності системи. Подається кроковий сигнал на вхід, і після цього визначається результат, тобто вихідний сигнал системи. Для контролю положення DC-двигуна рекомендується використовувати метод Циглера-Ніколса. Це двоетапний метод налаштування контуру, який фактично полягає в проведенні спеціального тесту для кількісної оцінки поведінки процесу, з точки зору того, як швидко і наскільки змінна процесу варіюється при зміні керуючого впливу (командного значення). На основі цього за певним набором емпіричних формул для переведення результатів цих тестів здійснюються відповідні налаштування продуктивності та параметри керування контролера. Суть методу полягає у визначенні критичного періоду T_u (ultimate period) та критичного коефіцієнта підсилення P_u (K_u) (ultimate gain). Під час цього контролер тимчасово відключає свій PID-алгоритм і замінює його на реле ON/OFF, яке змушує змінну процесу коливатися. Ці отримані величини добре описують поведінку процесу, щоб визначити, як слід налаштувати PID-регулятор, щоб отримати бажану продуктивність замкненого контура.

Ключові слова: інформаційно-вимірювальний комплекс, метрологія, вимірювання фізичних величин, PID-алгоритм, DC-двигун, похибка, стійкість, оцінювання якості.