DIGITAL CONTROL OF A DYNAMIC OBJECT

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CURRENTLY USED CONTROL SYSTEMS OF MANY ACTUALLY OPERATING TECHNOLOGICAL OBJECTS CONTAIN SEVERAL INTERCONNECTED CIRCUITS DESIGNED TO REGULATE AND STABILIZE VARIOUS PARAMETERS. IT IS KNOWN THAT IN MODERN CONTROL SYSTEMS THE CALCULATION OF CONTROL ACTIONS IS CARRIED OUT WITH THE HELP OF A DIGITAL CONTROLLER BASED ON INDUSTRIAL CONTROLLERS [8]. IN THIS CASE, THE GENERALLY ACCEPTED SCHEME OF CONTROL SIGNAL CONVERSION (FROM DIGITAL REPRESENTATION INTO A PULSE-WIDTH SIGNAL OF A GIVEN POWER) ASSUMES ITS DIGITAL-TO-ANALOG CONVERSION, WHICH FORMS A PULSE-WIDTH-MODULATED (PWM) SIGNAL WITH A DUTY CYCLE PROPORTIONAL TO THE CALCULATED AMPLIFICATION IN ACCORDANCE WITH THE INPUT SIGNAL. AND AMPLIFICATION OF THE RECEIVED SIGNAL. ON THE OTHER HAND, THE DESIRED PWM SIGNAL, REPRESENTED BY A SEQUENCE OF "ONES" AND "ZEROS" WITH A GIVEN DUTY CYCLE AND A FREQUENCY HIGHER THAN THE CONTROLLER FREQUENCY, CAN BE GENERATED AT THE OUTPUT OF THE MICROCONTROLLER (MC) BY SOFTWARE. THIS RESULTS IN LOWER HARDWARE COST AND HIGHER RELIABILITY OF THE ENTIRE CONTROL SYSTEM. IN THIS APPROACH, THE IC DOES NOT CALCULATE THE CONTROL SIGNAL ITSELF, IT CALCULATES THE FREQUENCY OF THE CORRESPONDING PWM SIGNAL.

Let the dynamics of a linear stationary discrete control system be described by difference equations:

$$x(i+1) = Ax(i) + Bu(i), \quad (1)$$

$$y(i) = Cx(i)$$

where, $x \in R^n, u \in R^m, y \in R^r, (r < n)$ - vectors of states, control and measured outputs, respectively; A, B, C - matrices of corresponding sizes forming the controlled and observed triplet.

It is required to find an algorithm for calculating the slope q(i) of the control PWM signal in such a way that the closed-loop control system is stable, giving the system the properties of astaticity and the necessary quality of transients with sharp jumps at load changes.

RMS value of pulse-width modulation of the signal depends on the (τ_u) pulse duration and pulse repetition period and is determined by the formula:

$$q(i) = \tau_u / T$$

In order to reduce the influence of the control signal ripple arising during its sampling, the sampling period of the PWM signal is selected much shorter than the smallest of the system time constants. In this case, the slope of the PWM control signal is calculated based on information from the relevant sensors and is kept constant throughout the current cycle. With this in mind, the discrete model of the PWM signal can be represented by a difference equation of the following form:

$$u(i+1) = q(i), \qquad (2)$$

where, $u(i)$ - discrete control signal.

In this case, if we consider that the input of the PWM link is a quadratic value, and the output is the average value of the control signal for the period under consideration, the PWM model can be represented as a linear-difference control of the first order, ie.

$$T\frac{dH}{dt} + H(t) = q(t),$$

where, T - time constant characterizing the inertia of the process.

The fill factor of the PWM signal is calculated only in the next cycle and its value does not change during this cycle.

Control systems with pulse-width modulation belong to the class of nonlinear systems. In this case, the pulse-width modulator (Fig. 1) is one of the main elements of modern microcontrollers designed to control technological objects. Calculation of the control signal for the PWM loop is carried out according to the following recurrence relation [23]:

$$y_{\sum i+1} = x_{i+1} - y_{i+1},$$

$$y_{\text{int}i} > 0 \; then \; y_{i+1} = 0 \; else \; y_{i+1} = y_i \qquad (4)$$

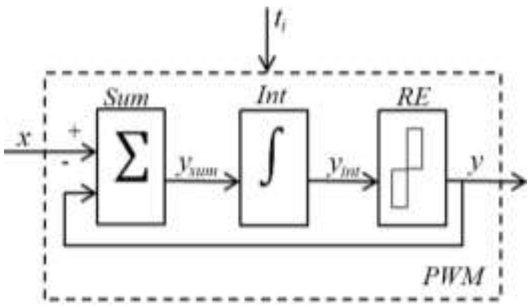

Fig. 1. Principle of PWM modulator operation

Sum - summation operation; Int - integration operation; RE - control signal limitation of relay element type with hysteresis.

where x_{i+1} - modulator input signal, y_{i+1} - modulator output signal. A- output signal level limited by the relay element, $a = A - t_i$,- insensitive zone of the relay element, t_i - pulse duration, $y_{int\, j+1}$ - output signal of the modulator integrating element. T_0 - time constant of the integrating element of the modulator, y_{sumj+1} - output signal of the summing element. The principle of operation of the modulator is to convert the input signal, i.e. the error signal, into a sequence of rectangular pulses. In this case, the duration of the rectangular signal is directly proportional to the magnitude of the error signal (Fig. 2.).

In a control system, the error signal is determined by the difference between the setpoint and the current value of the controlled process.

The output signal of the control object is usually measured by a sensor, and in the absence of a sensor, the values of the output signal are determined by the mathematical model of the control object. In this case, using the convolution theorem, the value of the output signal of the control object at each time step is calculated by the formula:

$$y(t) = \int_0^t \omega(\tau_u) u(t - \tau_u) d\tau_u ,$$

Where is $\omega(\tau_u)$ - weight function determined by the transfer function of the object; $u(t - \tau_u)$ - object input signal.

The algorithm generates a sawtooth signal, which is compared with the error signal.

If the error signal es decreasing, the integrator slows down the growth of the error signal and overshoots the transient response of the control system. Compensation of the error signal depends on the time constant of the object T_s . The T_s value is assumed to be equal to the pulse duration at each cycle. To limit the output system of the regulator, the limitation on the differentiating component is used in the form of $[U_{MAX,}$ - U $]._{MAX}$

It is known that at small perturbations and at steady-state operation the PID controller is linear. However, the process of entering the mode associated with the setpoint change must take into account the nonlinearity of the "limitation" type associated with natural technological limitations The manifestation of the limitation mode is called integral saturation, which leads to a prolongation of the transient process. To reduce the influence of integral saturation, the paper proposes the introduction of additional feedback into the control loop, which allows compensating the signal fed to the integrator input.

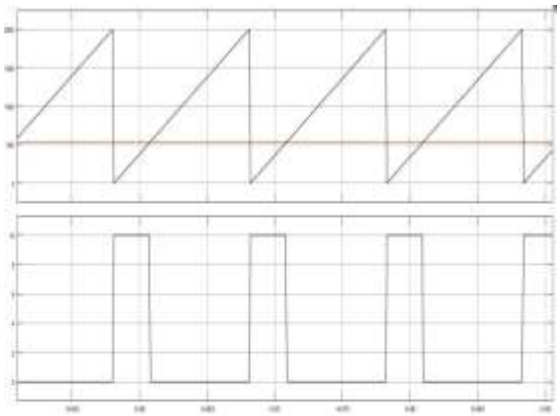

Figure 2 - Signal conversion using PWM.

The modulator operation algorithm is as follows: A sawtooth signal is applied to the modulator, which is compared with the control error signal. If the control signal is greater than the signal generated in the algorithm, the output is a logical 1 corresponding to the supply voltage, otherwise 0 [20].

Existing methods for investigating the dynamics of a control system with a PWM modulator are based on recurrence methods or on methods using phase plane concepts [20]. To date, there are a large number of systems for the study of which the known approaches are not suitable, or there are fundamental difficulties associated with non-standard modes of operation of pulse width modulators. In addition, in multidimensional control systems with

PWM modulators the pulse repetition periods may be different, i.e. the modulator operation modes are asynchronous. In this case, the methods used in the study face some difficulties associated with the calculation of output variables from the modulation characteristics of pulse elements, which becomes an additional source of difficulties in the study of operating modes of pulse parts of the control system [3].

The proposed algorithm for digital control of the PWM signal pulse width shows that the PWM model turns out to be linear and practically inertia-free, which makes it easy to take this model into account when synthesizing the control algorithm. The pulse width calculated at the current sampling step from the measured variables is taken as the control PWM signal. A control algorithm based on a hybrid application of the linear-quadratic optimization procedure and the theory of observers of minimum dimensionality is proposed. To ensure the fulfillment of the conditions of astaticity, the dynamic model of the object is supplemented with a discrete integrator.

ЛИТЕРАТУРА

1.М.А. Ахмад, Р.М.Т. Раджа Исмаил, М.С. Рамли, Н.М. Абд Гани и Н. Хамбали. Исследование методов обратной связи для управления против раскачивания трехмерной системы козлового крана. 2009 IEEE Symposium on Industrial Electronics & Applications, Kuala Lumpur, Malaysia, 2009, pp. 265-270, https://doi.org/10.1109/ISIEA.2009.5356445.

2.Бенджамин К. Куо, Фарид Голнараги. Системы автоматического управления. Нью-Йорк, John Wiley; 8 издание. 2002. - 624 p.

3.Кулаков Г.Г., Кравченко В.В., Макоска Ю.В. Методика расчета экономической эффективности внедрения инновационных систем автоматического управления ТЭС (часть первая). Наука и техника. 2012;(5):92-97. (In Russ.).

4.Кацухико Огата. Современная инженерия управления. Pearson Higher Ed USA. 5 edition. 2009. -912 p.

5.Ричард К. Дорф, Роберт Х. Бишо. Современные системы управления. Pearson Higher Ed USA; 12 edition, 2010. -1104 p.

6.Автоматизация управления - теория и практика. Под редакцией А.Д.Родича, Технолог, 2009. - 360 p.

7.Астром К. Дж. (2006) Усовершенствованное ПИД-регулирование/ К. Дж. Астром, Т. Хаглунд - ISA (The instrumentation, Systems, and Automation Society), 2006 - 460 с.

8.Сиддиков, И. К., и Рустамова, М. Б. (2020). Расчет непрерывных дискретных систем с множественными синхронными прерываниями//Американский журнал техники и технологии. 2020. 2(08), 85-93. https://usajournalshub.com/index.php/tajet/article/view/826/779