# Pseudo-linear correction as a means of improving the quality of control systems

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**Abstract**. The work shows the possibility to improve the quality of automatic control systems by applying the controller which includes a pseudo-linear correcting device with phase advance, one proportional and one differential element and an integrating link based on the Clegg integrator. The conducted research shows that such approach to constructing automatic control systems enables to improve significantly the performance indices for transient processes when controlling objects whose parameters change their values over time. The work concludes that the use of such systems is possible and appropriate for non-stationary objects when changing their parameters in quite a wide range.

## 1. Introduction

Controlling a non-stationary object is rather challenging because it is quite difficult to predict in advance at what moment and by what value the parameters of the test object will be subject to change.

There are several approaches to controlling non-stationary objects. One of them implies calculating new coefficients for the controller when changing parameters of the test object. Nevertheless, this approach has one constraint regarding the necessity to break the feedback and identify the test object for calculating new coefficients. Doing this, the object is left uncontrolled for a while, which is unacceptable.

The work proposes a new approach to controlling non-stationary objects, which requires the use of a controller in the automatic control system. The controller consists of one proportional and one differential element, and an integrating link based on the Clegg integrator [1]. It is supplemented with a pseudo-linear correcting device with phase advance [2].

## 2. The structure of the controller

Figure 1 shows the structure of the proposed controller where PA is a pseudo-linear correcting device with phase advance, P is a proportional element, CI is the Clegg integrator and D is a differential element.

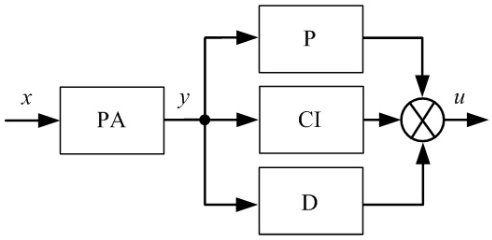


**Figure 1.** The controller

Figure 2 depicts the diagram of the pseudo-linear correcting device with phase advance.

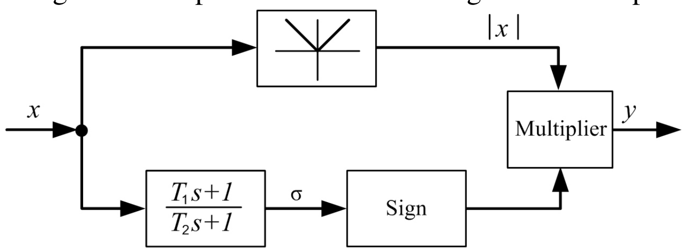


**Figure 2.** The pseudo-linear correcting device with phase advance

The correcting device is made up of a signal allocation unit, a phase-advance element, a block definition of the sign and a multiplier.

PA harmonic linearization has the following coefficients:

$$a = \frac{1}{\pi}(\pi - 2\alpha + \sin 2\alpha); \quad b = \frac{1}{\pi}(1 - \cos 2\alpha),$$

$$\alpha = \mathrm{arctg}\frac{\omega T_1(1-v)}{1+\omega^2 T_1^2 v}; \quad v = \frac{T_2}{T_1}.$$

where

The coefficients a and b of the given PA depend on the input frequency. Amplitude and phase characteristics of PA, defined by equations

$$A(\omega) = \sqrt{a^2 + b^2}; \qquad \varphi(\omega) = \mathrm{arctg}\left(\frac{b}{a}\right),$$

also depend on the input frequency and do not depend on its amplitude.

The forms of signals at the particular PA points (Figure 2 respectively) are shown in Figure 3.

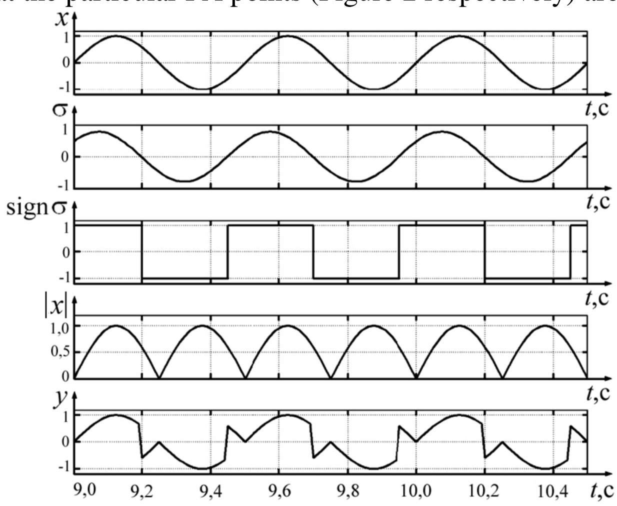


**Figure 3.** Curves at the points of the pseudo-linear correcting device

In Figure 3, the curves correspond to the forms of signals, given that the values of PA parameters are $T_1$=5s, $T_2$ =0,1s and sinusoidal input frequency is equal to 2 Hz.

Analysis of PA frequency characteristics shows that changing the input frequency and varying the values of time constants of the phase-advance element, $T_1$ from 1 to 10s and $T_2$ from 1 to 0,01s, lead to the changes in the phase characteristic from 0 to 78°. Similarly, this brings about changes in the log amplitude-frequency characteristic (Bode diagram) from 0 to –4 dB [3]. The latter, however, does not significantly influence the amplitude stability margin of the automatic control system. The correcting device performs a positive phase shift which value depends on values $T_1$ and $T_2$. The correcting device is applied to improve the performance indicators.

The diagram of the Clegg integrator is shown in Figure 4.

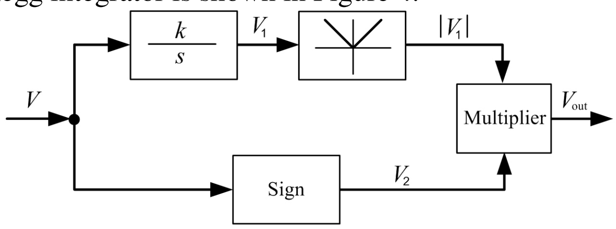


**Figure 4.** Clegg integrator

The Clegg integrator includes an integrating unit, a signal allocation unit, a block definition of the sign and a multiplier.

The advantage of such integrator is that it has a relatively small phase lag applied to the system.

## 3. Researches and results

Figure 5 presents the model of the automatic control system designed with Matlab 7.12 to research the proposed controller. The model has two subsystems with identical test objects. The upper subsystem uses a classic PID-controller, whereas the lower one uses the type of the controller shown in Figure 1.

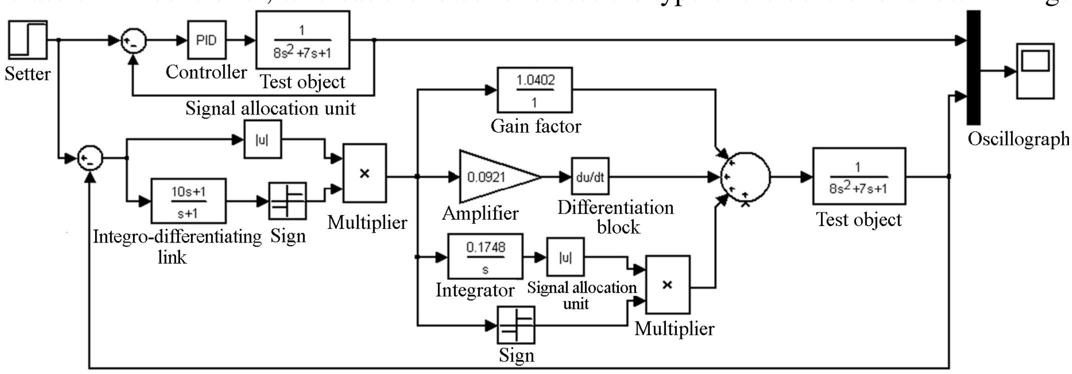


**Figure 5.** The model in MatLab 7.12

The model has identical second-order test objects whose transfer function looks like:

$$W_o(s) = \frac{K_o}{T_2{}^2 s^2 + T_1 s + 1},$$

where $K_o$ is the transmission gain, $T_1$ and $T_2$ are time constants of the test object. Its values are as follows: $K_o$=1. $T_1$=2.82842 s. $T_2$=7 s.

Describing the test object, based on the Ziegler–Nichols tuning method, needs indices of a classic PID-controller are to be determined, which facilitates an aperiodic transient response. The indices are $K_p$= 1.0402. $K_i$= 0.1748. $K_d$= 0.0921.

In order to study the properties of control systems, the proposed controller was tuned, i.e. differential and proportional values were assumed equal to those of a classic PID-controller. The process control setting of the Clegg integrator was therefore assumed equal to the integral gain of a classic PID-controller. Thus, PA setting parameters are as follows: $T_1$=10 s, $T_2$=1 s.

Figure 6 shows the curves of transient processes that correspond to the subsystems of the control system having parameters of the test object and values of the controllers described above.

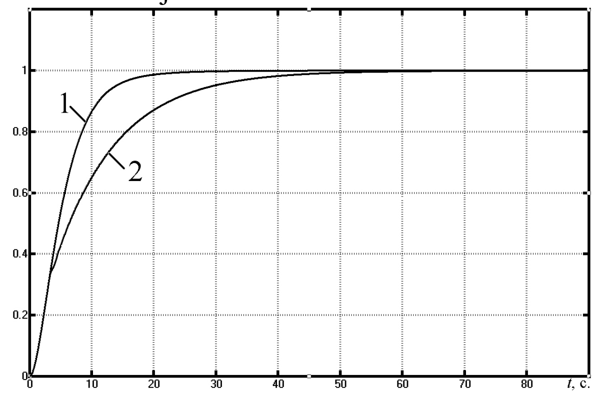


**Figure 6.** Curves of transient processes

In Figure 6, the curve denoted as 1 corresponds to the transient curve of a classic PID-controller, whereas curve 2 – to that of the proposed controller. The Y-axis is calibrated in relative units. From this, it is seen that the transient response is aperiodic. By comparing these two subsystems, the conclusion is that the subsystem with the proposed controller has a longer settling time.

After that, to demonstrate the performance characteristics of the proposed controller, the parameters of the test object were also changed. The changed values are: $K_o$=1. $T_2$=5.4772 s. $T_1$=3 s. In addition, coefficients of both types of controllers remain the same and are equivalent to the initial conditions.

Figure 7 shows the transient curves for the same two subsystems of the automatic control system, but having modified values of the test object parameters.

In Figure 7, the curve denoted as 1 corresponds to the transient curve of a classic PID-controller, whereas curve 2 – to that of the proposed controller.

The Y-axis is calibrated in relative units.

As seen from Figure 7, a classic PID-controller, when having the changed parameters of the test object, does not provide an aperiodic transient response. Moreover, its performance indicators do not meet the requirements. The control system, however, manages to keep the stability. As regards the performance indices of the control system with the proposed controller, they remain satisfactory and ensure an aperiodic transient response, which proves the efficiency of the proposed controller.

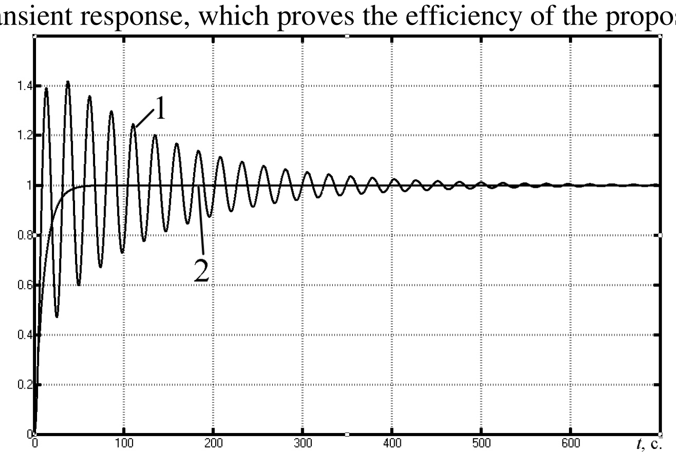


**Figure 7.** Curves of transient processes

The control system with the proposed controller remains stable, even when the time constant of the test object is $T_2$=70 s. On the contrary, the control system with a classic PID-controller loses its stability, even when the time constant of the test object is just $T_2$=6 s.

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## 4. Conclusion

The conducted research let us eventually resume that the control system with the proposed controller is rather efficient when test object parameters change their values in quite a wide range. Accordingly, it follows that the proposed controller can be referred to as robust.

The given work describes the controller which includes a pseudo-linear device with phase advance. The phase characteristic varies within the range of 0 to 78°. When phase-frequency characteristic is required to be increased by the value more than 78°, one can apply the type of an extremum pseudo-linear device [4]. This device enables the rise in the phase-frequency characteristic up to 175°.

## 5. Acknowledgments

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