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System two-position control of liquid level in industrial tanks

Andrey A. Zakamaldin, Vladimir S. Andyk

National Research Tomsk Polytechnic University, 634050 Tomsk, Russia

Abstract. Design of the automatic liquid level control was performed for the tank rectangular type with the presence of self-regulation. Were found settings of two-position automatic controller with a zone of ambiguity with symmetric static characteristic. Settings meet the specified requirements for the automatic control system. Opportunities and stability of self-oscillations of the controlled variable were assessed by the method of harmonic balance. Was created a virtual model of single-circuit system two-position control of liquid level and estimates the quality of regulation.

1. Introduction

In the development of controls noticeable significant progress due to the transition to the new microelectronic element base. The uses of microelectronics require the adoption of new technical solutions, including economically inexpedient. In this regard, along with sophisticated control devices, where the terms of the technology no strict requirements for quality control, microelectronics replace most cheap, easy adjustment and reliable operation of the two-position automatic controllers.

Two-position controller - it's such a controller, the magnitude of the output signal which can take only two values established. Also flow of energy or substance to a regulated entity can only be a maximum or minimum.

Why two-position controllers? Of course, these regulators are simple, reliable and cheap which is especially important, but because it is based on non-linear control law, the actual value will constantly fluctuate in a certain range. This condition is unacceptable for use in modern automation schemes, where the main indicator is the quality of regulation. Maintain the fluid level at a predetermined value in the ordinary tank is not very demanding process, and fluctuations in the level allowed. In this process two-position control highly advisable. For that would confirm it and get an idea of the possibility of using on-off controls was carried out this work.

2. Problem statement

We considered technological process control of liquid level in the tank of a rectangular type (Figure 1) with the structural characteristics: the length of the tank a=10 m, the width of the tank b=10 m, height of the tank h=7 m. Was assumed that the fluid flow enters the reservoir average consumption Q_0=50 m^3/h through conduit length l=30 m and a diameter of d=0,2 m. Requirements for automatic control system:

1. Maintaining water level in the tank at a height h_0=5 m.
2. Allowable range of fluctuation level Δh=1 m.
3. Not exceeding a switching frequency (self-oscillation) n=20 h^{-1}.

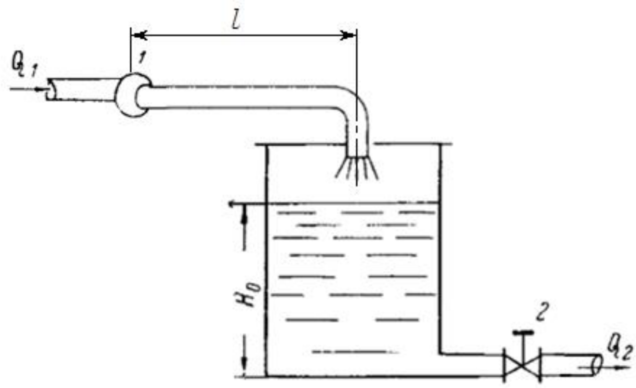

Figure 1. The object of regulation with automatic compensation.

Technological process occurring in industrial reservoir requires maintaining a predetermined liquid level value, it is necessary to change the material flow entering the unit, in this case, change the supply (flow) of the liquid inlet. The operating mode can be characterized by the presence or absence of self-alignment. Self-leveling - property of an object, due to which the value of the setpoint without the regulator seeks a new steady-state value, when the load changes the object (inflow or runoff). The presence of self-regulation in the facility is beneficial to the process of automatic control. To ensure stable automatic adjustment in this case is usually much simpler task than if the object does not have or has a too small ability to self-leveling. Therefore, consider a system with two-position controller is for objects with automatic compensation.

As a two-position automatic regulator was chosen electrocontact gauge. Sensor of the regulator is a pressure gauge for measuring the pressure and simultaneous control of external circuits. Digital signal from the controller is fed to the actuator (motor pump) through the starter. Thus, running preconfigured feedback, allowing you to control and modify the flow rate at the inlet to the tank. So system can be represented by the scheme (Figure 2).

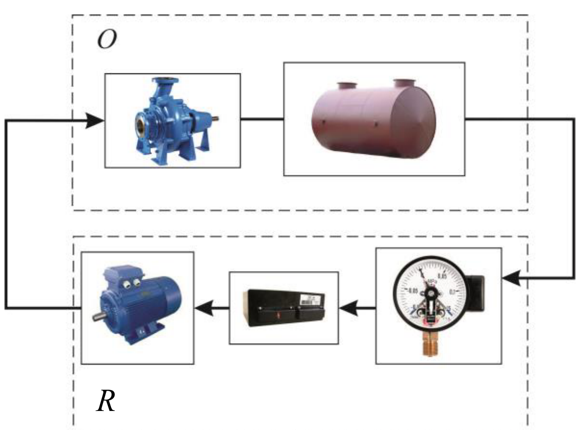

Figure 2. System two-position control level in the tank.

3. Mathematical model

For the mathematical description of control system, that is, to obtain static and dynamic characteristics use analytical methods that are based on the equations describing the physical, chemical and energy processes in the management of the object under study. In particular, the laws of conservation of energy and matter (material balance equation). The resulting transfer function for the controlled object is a series-connected aperiodic link and link of the delay:

$$W_{\text{об}}(p) = \frac{K}{Tp+1}e^{-p\tau} = \frac{2\sqrt{h_0}}{2S\sqrt{h_0}p+\alpha}e^{-p\tau}.$$

The object is connected in series with a two-position automatic controller with a static characteristic of a zone of ambiguity with an equivalent transfer function obtained by harmonic linearization:

$$W_{\text{н}}(iA) = \frac{4c}{\pi A^2}\sqrt{A^2-b^2} - i\cdot\frac{4cb}{\pi A^2}.$$

Assessment of the feasibility and sustainability of self-oscillations of the controlled variable and define the settings of the controller was performed by the method of harmonic balance (Figure 3). In the complex plane is constructed Nyquist plot of linear part of the system with an intervals ω=0.001 rad/s. Solving the equation of harmonic balance for a given oscillation frequency ω_k=0.0174 rad/s, we obtain controller settings b=0.261 and c=0.673.

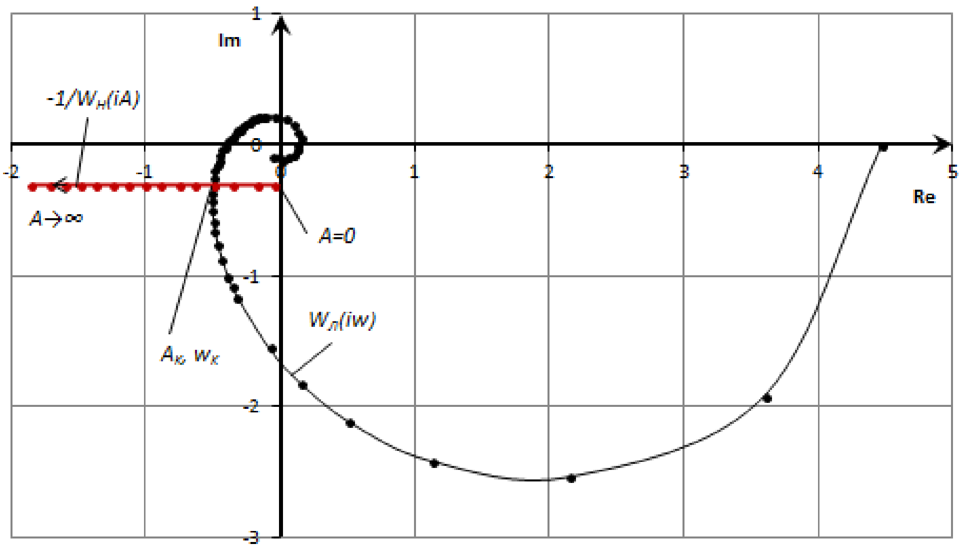

Figure 3. Graphical solution of harmonic balance.

The point of intersection graphs W_L *(iω)* and *(-1) / (*W_N *(iA))* corresponds to the set parameters of self-oscillation: amplitude and frequency A_k , ω_k. Hodographs overlap, therefore the occurrence of self-oscillation due to the first harmonic component of the output signal of the nonlinear element is possible.

From the point of intersection in the direction of increasing the amplitude *A* branch *(-1) / (*W_N *(iA))* lies outside the area covered by Nyquist plot of linear part (Figure 3). Consequently, the oscillations are stable.

4. Results and discussion

So, we got the control parameters for now to be able to assess the quality of regulation is necessary to construct the transition process. To build process manually, there are points not rational because the formula of the transient response is defined implicitly as the present non-linear element. We have taken advantage of the program Scilab 5.5.0, using the visual modeling Xcos. The resulting transient response reflects fluctuations in the value of the water level in the tank over time. Seen from the graph that the value of the level fluctuates around the desired setpoint is initially 5 m (Figure 4). To assess the quality of regulation, carried out an analysis of the simulated process and compared the main indicators of quality control with the specified. Since the system of non-linear parameters of quality are the oscillation period and the range of fluctuations of the regulated quantity.

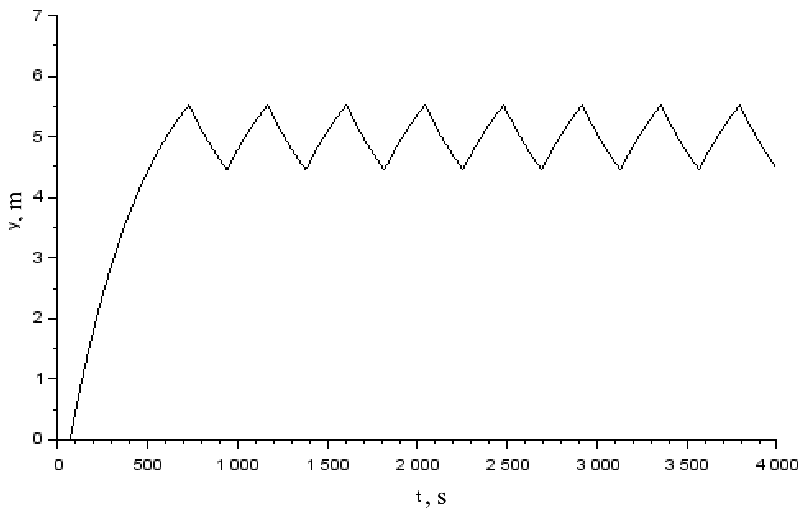

Figure 4. Transient response with respect to the reference variable.

Deviation obtained from the set of indicators are shown below

$$\delta T = \frac{T_{K\,set} - T_{K\,mod}}{T_{K\,set}} \cdot 100\% = \frac{418 - 361}{361} \cdot 100\% = 15{,}8\ \%.$$

$$\delta \Delta x = \frac{\Delta x_{set} - \Delta x_{mod}}{\Delta x_{set}} \cdot 100\% = \frac{1 - 1.09}{1} \cdot 100\% = 9\ \%.$$

As you would expect the deviation is present, indicating that not enough high quality regulation. And what we actually want, if the setting of the controller is quite simply setting a shooter electrocontact pressure gauge in position by appropriate configuration parameters, and does not require any special skills from the wait staff.

5. Conclusions

This way was obtained the settings two-position control for maintaining the water level in the tank at a height 5 m. The results showed that the on-off controls provide a decent quality control especially for inertial objects with a small delay and the presence of self-regulation. The scheme is economical, easy to use and configure.

References

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