International Journal of Automatic Control System
Vol. 1: Issue 1
www.journalspub.com

Review of Automatic Control Systems and Their Types

Disha Agre
Department of EEE, Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu, India

Abstract
Automatic control applies to the system applications of control theory for carrying out several sets of processes together without any role of humans or human interference. In any simplest type of control loop a controller is set to measure the desired process values. Such a closed loop control system is just how a negative feedback system is applied in a system. And designing of such an automatic controlling system requires addition of feed in the form of electrical energy for enhancing features of disturbed or errant system. And the feed in the form of electrical energy is regulated for implementing automatic control to the system with a set of or several devices.

Keywords: *Accuracy, digital signals, transportation system circuits, transformation, loop control systems*

***Author for Correspondence:** *Email ID: Dishaagre.mse@yahoo.com*

INTRODUCTION

A system or set of devices,which manage, command, direct and also regulate the behaviors of other device(s) or system(s) in-order to achieve desire results. In other words the definition of control system can be rewritten as: Automatic control system is a system, which can operate and control various sets of devices of systems. When few numbers of elements are added to form for producing some desired outputs, such systems are referred to as automatic control systems[1]. Every element connected to this system has an own effect on the output generated collectively or individually by the systems.

As the human civilization is being modernized day by day the demand of automation is increasing accordingly. Automation highly requires control of devices. In recent years, control systems plays main role in the development and advancement of modern technology and civilization. Practically every aspect of our day-to-day life is affected less or more by some control system. A bathroom toilet tank, a refrigerator, an air conditioner, a geyser, an automatic iron, an automobile; all are control systems. These systems are also used in industrial process for more output. We find control systems in quality control of products, weapons system, transportation systems, power system, space technology, robotics and many more. The principles of control theory are applicable to engineering and non-engineering field both.

FEATURES AND REQUIREMENTS OF GOOD CONTROL SYSTEMS

The main feature of control system is that there should be a clear mathematical relation between input and output of the system. When the relation between input and output of the system can be represented by a linear proportionality, the system is called linear control system[2]. Again when the relation between input and output cannot be represented by single linear proportionality, rather the input and output are related by some non-linear relation, the system is referred as non-linear control system. Below are the requirements of good control system:

Accuracy

Accuracy is the measurement of tolerance of the instrument and defines the limits of the errors made when the instrument is used in normal operating conditions. Accuracy can be improved by using feedback elements. To increase accuracy of any control system error detector should be present in control system.

Sensitivity

The parameters of control system are always changing with change in the surrounding conditions, internal disturbance or any other parameter. This change can be expressed in terms of sensitivity. Any control system should be insensitive to such parameters but sensitive to input signals only.

Noise

An undesired input signal is known as noise. A good control system should be able to reduce the noise effect for better performance.

Stability

It is an important characteristic of control system. For the bounded input signal, the output must be bounded and if input is zero then output must be zero then such a control system is said to be stable system.

Bandwidth

An operating frequency range decides the bandwidth of control system. Bandwidth should be as large as possible for frequency response of good control system.

Speed

It is the time taken by control system to achieve its stable output. A good control system possesses high speed. The transient period for such system is very small.

Oscillation

A small numbers of oscillation or constant oscillation of output tend the system to be stable.

TYPES OF CONTROL SYSTEMS

There are various types of control systems but all of them are created to control outputs. The system used for controlling the position, velocity, acceleration, temperature, pressure, voltage and current etc. are examples of control systems. We take an example of simple temperature controller of the room, for clearing the concept:

Suppose there is a simple heating element, which is heated up as long as the electric power supply is switched on. As long as the power supply switch of the heater is on the temperature of the room rises and after achieving the desired temperature of the room, the power supply is switched off. Again due to ambient temperature, the room temperature falls and then manually the heater element is switched on to achieve the desired room temperature again. In this way one can manually control the room temperature at desired level. This is an example of manual control system. This system can further be improved by using timer switching arrangement of the power supply where the supply to the heating element is switched on and off in a predetermined interval to achieve desired temperature level of the room. There is another improved way of controlling the temperature of the room.

Here one sensor measures the difference between actual temperature and desired temperature. If there is any difference between them, the heating element functions to reduce the difference and when the difference becomes lower than a predetermined level, the heating elements stop functioning[3]. Both forms of the system are automatic control system. In former one, the input of the system is entirely independent of the output of the system. Temperature of the room (output) increases as long as the power supply switch is kept on. That means heating element produces heat as long as the power supply is kept on and final room temperature does not have any control to the input power supply of the system.

This system is referred as open loop control system. But in the latter case, the heating elements of the system function, depending upon the difference between, actual temperature and desired temperature. This difference is called error of the system. This error signal is fed back to the system to control the input. As the input to output path and the error feedback path create a closed loop, this type of control system is referred as closed loop control system[2]. Hence, there are two main types of control systems; open loop control systems and closed loop control systems.

Open Loop Control System

A control system in which the control action is totally independent of output of the system then it is called open loop control system[1]. Manual control system is also an open loop control system. Figure 1 shows the block diagram of open loop control system in which process output is totally independent of controller action.

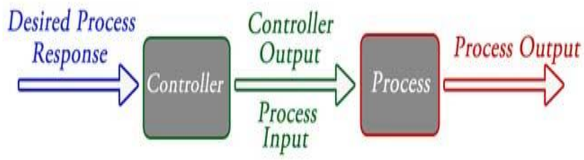

Fig. 1: *The Block Diagram of Open Loop Control System.*

Practical Examples of Open Loop Control Systems

1. Electric hand drier: Hot air (output) comes out as long as you keep hand under the machine, irrespective of how much your hand is dried.
2. Automatic washing machine: This machine runs according to the pre-set time irrespective of washing is completed or not.
3. Bread toaster: This machine runs as per adjusted time irrespective of toasting is completed or not.
4. Automatic tea/coffee maker: These machines also function for pre adjusted time only.
5. Timer based clothes drier: This machine dries wet clothes for pre-adjusted time, it does not matter how much the clothes are dried.
6. Light switch: lamps glow whenever light switch is on irrespective of whether light is required or not.
7. Volume on stereo system: Volume is adjusted manually irrespective of output volume level.

Advantages of Open Loop Control System

1. Simple in construction and design.
2. Economical.
3. Easy to maintain.
4. Generally stable.
5. Convenient to use as output is difficult to measure.

Disadvantages of Open Loop Control System

1. They are inaccurate.
2. They are unreliable.
3. Any change in output cannot be corrected automatically.

Closed Loop Control System

Control system in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called closed loop control system. Open loop control system can be converted in to closed loop control system by providing a feedback[4].

This feedback automatically makes the suitable changes in the output due to external disturbance. In this way closed loop control system is called automatic control system[5]. Figure 2 below shows the block diagram of closed loop control system in which feedback is taken from output and fed in to input.

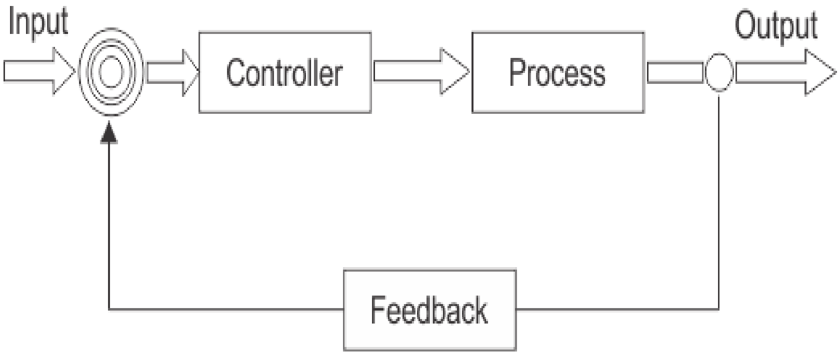

Fig. 2: *The Block Diagram of Closed Loop Control System.*

Practical Examples of Closed Loop Control System

1. Automatic electric iron: Heating elements are controlled by output temperature of the iron.
2. Servo voltage stabilizer: Voltage controller operates depending upon output voltage of the system.
3. Water level controller: Input water is controlled by water level of the reservoir.
4. Missile launched and auto tracked by radar: The direction of missile is controlled by comparing the target and position of the missile.
5. An air conditioner: An air conditioner functions depending upon the temperature of the room.
6. Cooling system in car: It operates depending upon the temperature which it controls.

Advantages of Closed Loop Control System

1. Closed loop control systems are more accurate even in the presence of non-linearity.
2. Highly accurate as any error arising is corrected due to presence of feedback signal.
3. Bandwidth range is large.
4. Facilitates automation.
5. The sensitivity of system may be made small to make system more stable.
6. This system is less affected by noise.

Disadvantages of Closed Loop Control System

1. They are costlier.
2. They are complicated to design.
3. Require more maintenance.
4. Feedback leads to oscillatory response.
5. Overall gain is reduced due to presence of feedback.
6. Stability is the major problem and more care is needed to design a stable closed loop system.

Comparison of Closed Loop and Open Loop Control System

Sr. No.	Open Loop Control System	Closed Loop Control System
1	The feedback element is absent.	The feedback element is always present.
2	An error detector is not present.	An error detector is always present.
3	It is stable one.	It may become unstable.
4	Easy to construct.	Complicated construction.
5	It is an economical.	It is costly.
6	Having small bandwidth.	Having large bandwidth.
7	It is inaccurate.	It is accurate.
8	Less maintenance.	More maintenance.
9	It is unreliable.	It is reliable.
10	Examples are; hand drier, tea maker	Examples are; servo voltage stabilizer, perspiration

Feedback Loop of Control System

A feedback is a common and powerful tool while designing a control system. Feedback loop is the tool which takes the system output into consideration and enables the system to adjust its performance to meet a desired result of system[6]. In any control system, output is affected due to change in environmental condition or any kind of disturbance. So one signal is taken from output and is fed back to the input. This signal is compared with reference input and then error signal is generated. This error signal is applied to controller and output is corrected. Such a system is called feedback system. Figure 3 below shows the block diagram of feedback system.

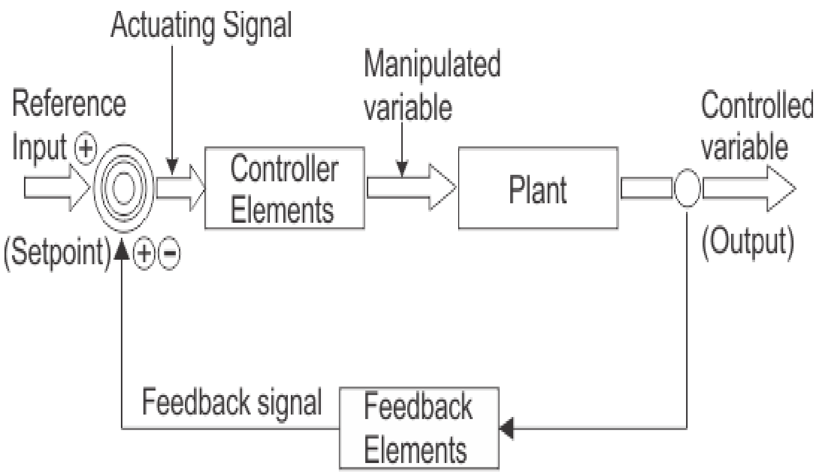

***Fig. 3:** The Block Diagram Feedback System.*

When feedback signal is positive then system is called positive feedback system. For positive feedback system, the error signal is the addition of reference input signal and feedback signal. When feedback signal is negative then system is called negative feedback system. For negative feedback system, the error signal is given by the difference of reference input signal and feedback signal.

Effect of Feedback

Figure 4 represents feedback system where R= Input signal E= Error signal G= forward path gain H= Feedback C= Output signal B= Feedback signal.

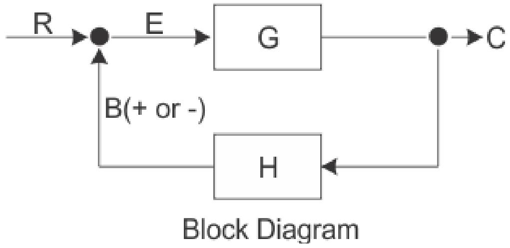

Fig. 4: *The Block Diagram Representing the Feedback System.*

1. Error between system input and system output is reduced.
2. System gain is reduced by a factor 1/(1±GH).
3. Improvement in sensitivity.
4. Stability may be affected.
5. Improves the speed of response.

TYPES OF CONTROL SYSTEMS: LINEAR AND NON LINEAR CONTROL SYSTEM

Before introducing the theory of control system it is very essential to know the various types of control systems. Now there are various types of systems, we are going to discuss only those types of systems that will help us to understand the theory of control system and detailed description of these types of systems are given below:

Linear Control Systems

In order to understand the linear control system, we should know the principle of superposition. The principle of superposition theorem includes two important properties explained below:

Homogeneity and Additivity

A system is said to be homogeneous, if we multiply input with some constant 'A' then output will also be multiplied by the same value of constant (i.e. A). Additivity: Suppose we have a system 'S' and we are giving the input to this system as 'a1' for the first time and we are getting output as 'b1' corresponding to input 'a1'. On second time we are giving input 'a2' and corresponding to this we are getting output as 'b2'. Now suppose this time we give input as summation of the previous inputs (i.e. a1+a2) and corresponding to this input suppose we are getting output as (b1+b2) then we can say that system 'S' is following the property of additivity. Now we are able to define the linear control systems as those types of control systems which follow the principle of homogeneity and additivity[7].

Examples of Linear Control System

Consider a purely resistive network with a constant dc source. This circuit follows the principle of homogeneity and additivity. All the undesired effects are neglected and assuming ideal behavior of each element in the network, we say that we will get linear voltage and current characteristic. This is the example of linear control system.

Non-linear Systems

We can simply define non-linear control system as all those systems which do not follow the principle of homogeneity. In practical life all the systems are non-linear systems.

Examples of Non-linear System

A well-known example of non-linear system is magnetization curve or no load curve of a dc machine. We will discuss briefly no load curve of dc machines here: No load curve gives us the relationship between the air gap flux and the field winding mmf. It is very clear from the curve given below that in the beginning there is a linear relationship between winding mmf and the air gap flux but after this, saturation has come which shows the non-linear behavior of the curve or characteristics of the non-linear control system[8].

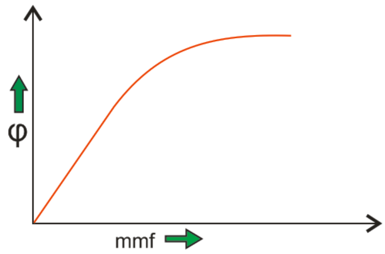

Fig. 5: *The Non-Linear System with its Magnetization Curve.*

ANALOG OR CONTINUOUS SYSTEM

In these types of control systems we have continuous signal as the input to the system. These signals are the continuous function of time[9]. We may have various sources of continuous input signal like sinusoidal type signal input source, square type of signal input source; signal may be in the form of continuous triangle etc.

Digital or Discrete System

In these types of control systems, we have discrete signal (or signal may be in the form of pulse) as the input to the system. These signals have the discrete interval of time. We can convert various sources of continuous input signal like sinusoidal type signal input source, square type of signal input source etc. into discrete form using the switch.

There are various advantages of discrete or digital system over the analog system and these advantages are written below:

1. Digital systems can handle non-linear control systems more effectively than the analog type of systems.
2. Power requirement in case of discrete or digital system is less as compared to analog systems.
3. Digital system has higher rate of accuracy and can perform various complex computations easily as compared to analog systems.
4. Reliability of digital system is more as compared to analog system. They also have small and compact size.
5. Digital system works on the logical operations which increases their accuracy many times.
6. Losses in case of discrete systems are less as compared to analog systems in general.

Single Input Single Output Systems

These are also known as SISO type of systems. In this, the system has single input for single output. Various examples of this kind of system may include temperature control, position control system etc.[8].

Multiple Input Multiple Output Systems

These are also known as MIMO type of systems. In this, the system has multiple outputs for multiple inputs. Various examples of this kind of system may include PLC type system etc.

Lumped Parameter System

In these types of control systems the various active (resistor) and passive parameters (like inductor and capacitor) are assumed to be concentrated at a point and that’s why these are called lumped parameter type of systems. Analysis of such type of system is very easy which includes differential equations.

Distributed Parameter System

In these types of control systems the various active (resistor) and passive parameters (like inductor and capacitor) are assumed to be distributed uniformly along the length and that’s why these are called distributed parameter type of systems[10]. Analysis of such type of system is slightly difficult which includes partial differential equations.

Digital Data of Control System

In the present article we will discuss all about discrete signals which are made up of discrete data or sampled data also known as digital data of control system. Now it is found that there is need of a digital technology though we have analog systems. The first few advantages of digital system over analog system are given below:

1. Power consumption is less in digital system as compared to analog system.
2. Digital systems can handle non-linear system easily which is the most important advantage of digital data in control system.
3. Digital systems work on the logical operations, due to this they show decision making property which is very useful in the present world of machines.
4. They are more reliable as compared to analog systems.
5. Digital systems are easily available in compact size and have light weight.
6. They work on instructions, so we can program them as per our needs hence they are more versatile than analog systems.
7. Various complex tasks can be performed easily with the help of digital technology with a high degree of accuracy.

We have a continuous signal; then how will you convert this continuous signal into discrete signal? Answer to this question is very simple; by the help of sampling process. Sampling process is defined as the conversion of analog signal into the digital signal with the help of a switch (also known as sampler). A sampler is a continuous ON and OFF switch which directly converts analog signals into digital signals[11].

We may have a series of connections of samplers; depending upon the conversion of signals, we use them. For an ideal sampler, the width of the output pulse is very small (tending to zero). While talking about discrete system, it is very important to know about the z transformations. Role of z transformation in discrete systems is same as Fourier transform in continuous systems. Now let us discuss z transformation in detail.
We define z transform as:

$$f(z) = \sum_{k=-\infty}^{\infty} f(k) z^{-k}$$

Where F(k) is a discrete data Z is a complex number F (z) is Fourier transform off (k). Important Properties of z transformation are written below Linearity: Let us consider summation of two discrete functions f (k) and g (k) such that:

$$p \times f(k) + qg(k)$$

Such that p and q are constants, now on taking the Laplace transform we have by property of linearity:

$$Z[p \times f(k) + q \times g(k)] = p \times Z[f(k)] + q \times Z[g(k)]$$

Change of Scale: let us consider a function f(k), on taking the z transform we have:

$$Z[f(k)] = f(z)$$

Then we have by change of scale property:

$$z[a^k f(k)] = f\left(\frac{z}{a}\right)$$

Shifting Property: As per this property:

$$Z[F(k + \ or \ -n)] = z^{(+ \ or \ -n)} f(z)$$

Now, let us discuss some important z transforms

$$Function\, f(t) = t$$

Laplace transformation of this function is 1/s2 and the corresponding f(k)=kT. Now the z transformation of this function is:

$$\frac{Tz}{(z-1)^2}$$

Function f (t)=t2: Laplace transformation of this function is 2/s3 and the corresponding f(k)=kT. Now the z transformation of this function is:

$$T^2 \times z \times \frac{z+1}{(z-1)^3}$$

$Function\, f(t) = e^{-at}$

Laplace transformation of this function is 1/(s+a) and the corresponding f(k)=e(–akT). Now the z transformation of this function is:

$$\frac{z}{z-e^{aT}}$$

$Function\, f(t) = te^{-at}$

Laplace transformation of this function is 1/(s+a)2 and the corresponding f(k)=Te-akT. Now the z transformation of this function is:

$$T\frac{e^{-aT}z}{(z-e^{-aT})^2}$$

$Function\, f(t) = sin(at)$

Laplace transformation of this function is a/(s2+a2) and the corresponding f(k)=sin(akT). Now the z transformation of this function is:

$$\frac{sin(aT)z}{z^2-2cos(aT)z+1}$$

$Function\, f(t) = cos(at)$

Laplace transformation of this function is s/(s2+a2) and the corresponding f(k)=cos(akT). Now the z transformation of this function is:

$$\frac{z^2-cos(aT)z}{z^2-2cos(aT)z+1}$$

Now, sometimes there is a need to sample data again, which means converting discrete data into continuous form. We can convert digital data of control system into continuous form by hold circuits which are discussed below:

Hold Circuits

These are the circuits which convert discrete data into continuous data or original data. There are two types of hold circuits and they are explained in detail:

Zero Order Hold Circuit: The block diagram of Figure 6(a) is the representation of the zero order hold circuit; is given below:

In the block diagram of Figure 6(b), we have given an input f(t) to the circuit, when we allow input signal to pass through this circuit it reconverts the input signal into continuous one. The output of the zero order hold circuit is shown below.

Now we are interested in finding out the transfer function of the zero order hold circuit. On writing the output equation we have:

$$F_o(t) = u(t) - u(t-T)$$

On taking the Laplace transform of the above equation we have:

$$F_o(s) = \frac{1}{s - \frac{1}{s \cdot e^{-sT}}}$$

From the above equation we can calculate transfer function as:

$$\frac{1-e^{-sT}}{s}$$

On substituting s=jω we can draw the bode plot for the zero order hold circuit. The electrical representation of the zero order hold circuit is shown below, which consists of a sampler connected in series with a resistor and this combination is connected with a parallel combination of resistor and capacitor[11].

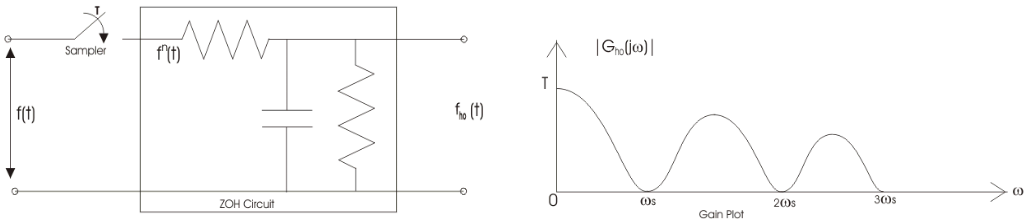

Fig. 6(a)(b): *The GAIN PLOT-Frequency Responses Curve of ZOH.*

PHASE PLOT - frequency response curve of ZOH PHASE PLOT - frequency response curve of ZOH.

First Order Hold Circuit: The block diagram of Figure 7 is the representation of the first order hold circuit, is given below:

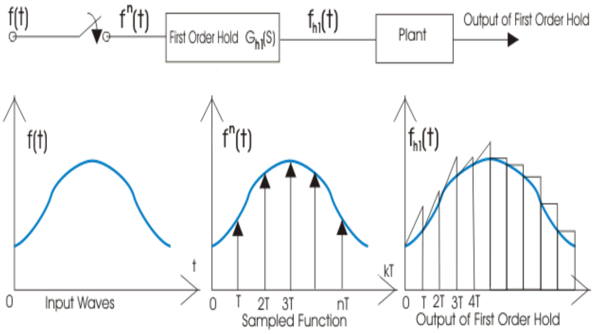

Fig. 7: *The First Order Hold Circuit.*

In the block diagram of Figure 8, we have given an input f(t) to the circuit, when we allow input signal to pass through this circuit it reconverts the input signal into continuous one. The output of the first order hold circuit is shown below. Now we are interested in finding out the transfer function of the first order hold circuit. On writing the output equation we have:

$$F_o(t) = (1+\frac{t}{T})u(t) - \frac{t-T}{T}u(t-1) - u(t-1)$$

On taking the Laplace transform of the above equation we have:

$$F_o(s) = \frac{(1-e^{-Ts} \times (Ts+1)}{Ts^2}$$

From the above equation we can calculate transfer function as (1–e–sT)/s. on substituting s=jω we can draw the bode plot for the zero order hold circuit. The bode plot for the first order hold circuit is shown below which consists of a magnitude plot and a phase angle plot. The magnitude plot starts with magnitude value 2π/ωs.

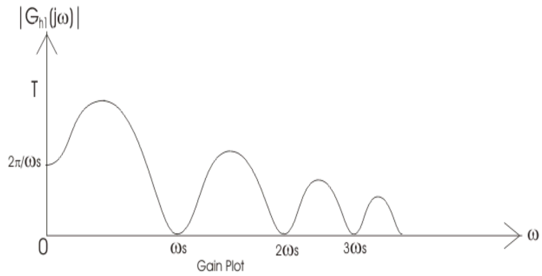

Fig. 8: *The Gain Plot of First Order Hold Circuit.*

CONCLUSION

The objective of control in one form or another has to do with the temporal variation of the regulated (controlled) quantity: the output variable of the controlled object. In order to accomplish the control objective while taking into account the peculiarities of controlled objects that have various characteristics and the specific features of individual classes of systems, one organizes an action (the control action) on the object's control units. This action is also designed to compensate for the effects of external disturbances that tend to interfere with the required behavior of the controlled quantity. The control effect is produced by a control device (CD). Hence, the totality of interactions between the control device and the controlled object constitutes an automatic control system.

REFERENCES

1. http://encyclopedia2.thefreedictionary.com/Automated+Control+Systems
2. https://en.wikibooks.org/wiki/Control_Systems/Modern_Controls/
3. http://www.automaticcontrols.net/
4. Maxwell JC, Vyshnegradskii IA, Stodola A. *Teoriiaavtomaticheskogoregulirovaniia.* Moscow; 1949.
5. https://en.wikipedia.org/wiki/Automatic_control
6. www.electrical4u.com/control-system-closed-loop-open-loop-control-sys.
7. Lerner AIa. *Vvedenie v teoriiuavtomaticheskogoregulirovaniia*. Moscow; 1958.
8. Fel'dbaum AA. *Vycheslitel'nyeustroistva v avtomaticheskikhsistemakh.* Moscow; 1959.
9. Fel'dbaum AA. *Osnovyteoriioptimal'nykhavtomaticheskikhsistem.* Moscow; 1963.
10. Lerner AIa. *Nachalakibernetiki.* Moscow; 1967.
11. Solodovnikov VV. *Teoriiaavtomaticheskogoregulirovaniia.* Book 1. Moscow; 1967.

