# Generation Of Control Signals As A Function Of System Internal Parameters

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***Abstract*: Conditions of generation of control signals by gas systems are very important in some cases depending on system internal parameters such as: pipeline passage, properties of valves, their response rates, friction loss in pipelines, etc. This work proposes a new approach based on physico-mathematical models and arrangement of signal transmission in gas systems which makes it possible to improve quality of processed signals by determination of influence of system internal parameters.**

***Index Terms*: system parameter; control signals; optimum correlations; physico-mathematical models.**

## I. INTRODUCTION

Let us consider the main time stages of generation of control signals. They are comprised of the switching time of sensor for signal transmission to system input, the time of signal transmission via communication lines, the switching time of system receiver, the time of data processing in system, the switching time of element generating output (control) signal, its transmission via line, and the switching time of machine actuator. All these processes should be considered upon already selected physical resources.

## II. METHODS

### A. General description

Immediately after selection of physical resources the problem is formulated to develop device flowchart according to predefined algorithm. The flowchart can be developed using the sequencer method (multistage systems are considered) when the number of elements of system memory corresponds to the number of operations of process which should be controlled, or that the number of memory elements is less than the number of control signals.

### B. Algorithm

The first method is attractive because it enables construction of flowchart using uniform section, herewith, the times of generation of control signals are close to each other since the number of activations of logical contacts in each line of generation of control signals is the same and the lengths of internal communication lines are similar. In the second method the lengths of communication lines in generation circuits of control signals are different which leads to variations in system response times upon generation of various signals, however, total number of flowchart actuation in this case is lower than in the first method.

The response time of the developed control system strongly depends on its design. Two main approaches can be applied. In the first case the flowchart is subdivided according to functional or other properties. Herewith, it is operable and maintainable, however, its response time sharply deteriorates due to increase in the length of communication lines in the system. Upon the second approach, the system is represented structurally as a single ultimate device. Response time of such system is higher, however, in this case it is more difficult to detect failures, to perform maintenance, etc.

After selection of approach to system implementation with accounting for available resources, its approximate response time is determined on the basis of hardware specifications and time of signal transmission via communication lines.

While performing dynamic computations, peculiar attention should be paid to sequence of hardware actuation in the system (during generation of control signals) and alternation of charging and discharging commutation lines. All necessary computations should be performed prior to actual fabrication of the system, that is, during system development. Response time of relay system can be improved by application of special devices in commutation lines which should be adjusted for certain time of signal passage. However, actuation of these devices, as all other system elements, requires for time which should be accounted prior to their installation in the system.

In initial works devoted to this issue the so-called prediction units were used in transmission lines of relay pneumatic signals in discontinuous lines. The essence of such approach is that in respective signal transmission line, a device is installed responding to minor deviation of gas (compressed air) pressure at its input. Herewith, the device generates a signal, its level can be increased or decreased (depending on charging or discharging) by certain preset value. The essence of increase in response time of cyclic pneumatic control systems is that at the system operation step preceding transmission of single control signal to communication line, this line is filled with compressed gas to certain pressure. This level is close to the actuation pressure of structural element to which the signal should be transmitted.

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At the next step the line is finally filled to maximum pressure starting from already reached pressure at previous step. In order to arrange the line discharge, the pressure is preliminary decreased at previous step with regard to the considered one to the level close to the actuation pressure of structural element receiving the signal. The proposed approach makes it possible to eliminate nearly completely the preliminary generation of control signal in its transmission line.

## III. RESULTS AND DISCUSSION

Let us consider two examples where the pressure of transmitted pneumatic signal is higher than the air pressure in communication line in initial state.

Example 1. The pipeline connecting the points A and B is under pressure $p_1^0$. Transmission of signal $p_c$ $(p_c > p_0^1)$ from A to B requires the time $t_1$ .

Example 2. The pipeline connecting the points A and B is under pressure $p_0^2$ where $(p_0^2 > p_0^1)$. Transmission of signal $p_c$ $(p_c > p_0^2)$ from A to B requires the time $t_2$ .

In the described examples $t_1 > t_2$ since in the first case higher time was required for pipeline filling to the pressure $p_c$ . It follows that the time of signal transmission via pipeline depends on the pressure of gas in pipeline in initial state. The proposed method is the most reasonable for decrease in switching time of machinery and system actuators characterized by high hysteresis in terms of control impact.

While analyzing physical models which describe filling of cavities of pneumatic apparatuses via signal transmission lines, it is possible to observe the influences of variables of these lines (diameters, distance, volumes of operating chambers of the apparatuses, etc.) which provide minimum time of system actitation. It is known, for instance, that at initial time at fixed pressure drops in the edges of communication line each its distance corresponds to certain diameter at which the transient process is more intensive. If a transmission line of lower passage area is used, then the friction loss increases and the transition process of line charging or discharging decelerates.

When the line diameter exceeds optimum values, the process also deteriorates but in this case as a consequence of increase in working volume.

The described phenomenon becomes clearer upon predictions of system dynamics using physico-mathematical models with accounting for distribution of gas variables (pneumatic signal) across spatial coordinates. It can be seen that if the diameter of communication line is lower than the optimum one for maximum rate of signal transmission, then the pressure wave propagating via the channel passes with high impulse losses; and when the channel diameter increases this wave passes via pipeline with lower losses, though its front is diffused across radius, hence high pressures and impulses are located only on the flow symmetry axis. In the latter case decrease in signal transmission rate can be attributed with the fact that device generating signal (gas flow) remains steady upon increase in diameter of communication channel. This results in that the passage area of this device does not provide the required gas flow rate.

If response time of the control system (without accounting for communication lines of signal transmission to and from the system) is unsatisfactory, then it is required to modify the system itself. Two approaches to solution of this problem can be applied. The first of them is comprised of variation of structure layout with accounting for obtaining minimum time of signal generation inside the system. The second approach implies replacement of elemental base. Sometimes solution can be reduced to variation of structure layout and its communication design with simultaneous replacement of hardware. In exclusive cases it is possible to combine various hardware, though, it is unreasonable due to deterioration of changeability of layout elements, maintainability, etc.

If the aforementioned measures do not provide the desired results, then sometimes it is possible to modify receiving units of signals transmitted by the control system so that these units would be activated at lower levels of control signals (upon transmission of single values of relay signals) and vice versa upon higher values of signals upon transmission of their zero values.

The aforementioned is related to the tasks where the stroke of receiving element resulting from signal transmitted from control system is low (membrane, for instance) and its switching time can be neglected. However, if control signals are transmitted to large reservoirs (for instance, to cavities of cylinders with significant stroke of pistons), then the time of charging or discharging of these reservoirs is high and should be accounted for upon development of overall control system at designing stage, namely, after formulation of the problem. Now let us consider in more details the process of generation of analog signals by control systems as a function of internal variables of these systems. While developing various engineering units, the systems are highly important which provide their operability according to requirements using the developed algorithms [1, 2]. Control signals also have their dimensionality and values. The required dimensionality of signal can be readily determined, it is more difficult to determine its required value (analog values are meant). The preset signal value at outlet of developed system can be determined upon correct (for the given problem) selection of system variables [3, 4] (that is, in certain sense optimum selection), these variables should be comprised both of external (inlet signals) and internal variables [5] characterizing the system itself. We should concentrate on selection of system internal variables, the external ones are considered to be preset. Let us specify the notion of system internal variable.For pneumatic hydromechanical system they can be as follows: passage areas of pipelines and valves, their response time, cylinder diameters, friction loss in pipelines and solid units.


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For data systems such variables can be considered as internal which effect on properties of output signal, including the time of its generation [6, 7].

Upon qualified development of any sufficiently complicated system, the number of internal variables can reach several tens. Sometimes it is impossible to select (to predict theoretically) optimum correlation of these variables in order to obtain the preset output signal, since the system developer (expert) should be acquainted with the theory of probability with regard to the considered problem [8].

In order to solve this problem approximately, which is often used in practice, it would be reasonable and efficient to apply certain targeted approach. It is as follows: initially weights are assigned to system internal variables (that is, determination of their importance in the considered problem, for instance, by expert appraisals), then the main of them are selected for further analysis. Let us consider a practice-oriented example.

Let us assume that the system internal variables (their values will be varied) are the variables $A, B, C$. At output the system generates the signal $D$, herewith, it is required to obtain its actual value $D^*$. The solution close to optimum is determined using transfer function $D^* = D^*(A,B,C)$ which in fact is a physico-mathematical model [9, 10] of transient process in the system. The more correct is the model, the higher is the quality of the result of the considered problem.

The solution is reduced to construction of minimum required plots of transient processes in the considered system and processing the obtained graphical data. At first, it is required to assign three values to each variable $A, B, C$: $A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3$, herewith, the extreme values of variable $A$ $(A_1, A_3)$ should correspond to practically achievable minimum and maximum (similar, the variables $B$ and $C$ ). Using computations by physico-mathematical model for $A = A_1$, we plot transfer function at fixed $B = B_1$ and varying $C = C_1, C_2, C_3$, that is, we obtain $D = D[A_1, B_1, (C)]$.

Then we predict and plot graphical dependences:

$$D = D[A_1, B_2, (C)];$$
$$D = D[A_1, B_3, (C)].$$

In order to obtain entire dependence of $D$ on the variables $B$ and $C$ at fixed $A$ ($A = A_2$ and $A = A_3$), we plot similarly the dependences $D = D\left[A_{2,3}, B_{1,2,3}, (C)\right]$.

Then we obtain:

$$D = D\left[B_{1,2,3}, C_{1,2,3}, (A)\right];$$
$$D = D\left[C_{1,2,3}, A_{1,2,3}, (B)\right].$$

It should be mentioned that with existing physico-mathematical model of transient process in the developed system, plotting of the aforementioned dependences for $D$ is not difficult, since it is reduced to simple replacement of the variables $A$, $B$ and $C$ which in fact are boundary conditions of the problem for each variant of computations.

Then, in all obtained plots for fixed value $D = D^*$ the straight line is drawn perpendicular to $D$ axis which intersects all graphical dependences. The intersection points meet the requirements of obtaining preset output signal $D^*$ on the basis of known values of the internal variables $A, B, C$. After simple analysis of the obtained graphical data with accounting for available embodiment of the system, the region on the line $D = D^*$ is determined for selection of $A, B, C$, including the solution close to optimum one. For final approval of the selected values of system internal variables, the checking calculation of $D$ is performed using physico-mathematical model in order to determine $D = D^*$. However, in certain cases it could be reasonable to perform additional backward calculation using physico-mathematical model at $D = D^*$ in order to select rational (with regard to technical embodiment) values of one of the variables $A, B, C$ on the basis of determined rational values of two of them.

## IV. CONCLUSION

1. This work discusses possible solution of problems aimed at improvement of response time of control systems while considering pneumatic systems as more inertial. It has been demonstrated that the required response time can be obtained both by specialized hardware and by modification of layouts of the considered systems and their communication variables.

2. Procedural approach to selection of optimum internal variables of the system for generation of preset output signal is based on processing of graphical data on system transient processes obtained using its physico-mathematical models, and can be applied for development of various control systems. Herewith, this approach makes it possible to select combination of system internal variables with accounting for their possible embodiment.

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