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Effective Control of the Activities of the Scientific School as a Multivariable Dynamic Object

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***Abstract*—The paper presents the results of modeling the control of the activities of scientific school. The scientific school is considered as a multivariable dynamic object. To control a scientific school as a complex dynamic object requires a high level of self-organization of the whole collective the form of three interconnected controlled subsystems. Each of subsystems seeks to achieve its goal for a specified given length of time and space. The peculiarity of such organization is that each member of the collective participates in the functioning of all three subsystems, performing the function assigned to it, while transferring their knowledge to their colleagues, without in any way reducing their own stock of knowledge. With collective control, a synergistic effect may occur, which stabilizes the oscillatory process, thereby increasing the stability of the control system.**

***Keywords*—science school, collective control, dynamic object, synergistic effect, stability**

I. Introduction

The scientific school is an integral part of the national potential of science and education. In the scientific literature it is considered as one of the main elements of the academic structure of science, as a source of new ideas and new technologies, as one of the most important factors in the development of the economy and society as a whole, as a source of training new generation scientific personnel [1–4].

Some researchers focus on the history of the scientific school and on the main world-level results obtained in it. Others - on the features of the leadership and activities of the leader of the scientific school. Third - on the features of the functions and characteristics of the scientific collective in a particular area of knowledge, etc.

In any case, all this information is mainly descriptive in the form of memories or descriptions and analysis of scientific results. But the question of how outstanding results are achieved in a creative collective does not give an answer.

The key characteristics of the "scientific personality" and how these relate to the laboratory communication environment that the technical supervisor should nurture and maintain are discussed in [5]. When successful, the unique needs of the researcher will be met by the provision of an atmosphere which will facilitate creativity. The creative work of research personnel is the primary product of the laboratory.

In [6] presents the results of exploring the structure and dynamics of the science community by means of the communicational analysis. The main stages of formation and development described by a cyclic model. The results of the analysis of publication activity are shown and the trend is revealed that the most important members might be the researchers, who have regularly published both individual and collective materials. Generally, they appear to be the leaders of some scientific schools, bringing their own concepts and then developing them in a team.

The article [7] ideas and educational practices linking educational activities and research studies both in the higher and secondary schools are presented. It is said that research education becoming a mission not only of a specific university (with its scientific schools), but also of a specific school. This allows you to form educational partnerships of schools, universities and research organizations. The conclusion has been made that at the end of the 20th century there appears an educational institution of a research type - the University and school - which uses the cognition methods inherent in a scientific search, is institutionalized in cluster-network forms and is based upon an educational innovation system.

Author Rozov N.S. in his work [8] he considers the ideal of national science as an imaginary model that meets a number of values. The following values are defined as values: the intrinsic value of knowledge and the growth of scientific knowledge, of development of philosophical thinking; openness and freedom of intellectual exchange, communication links, the unacceptability of scientific and educational exclusion; science must respond to the requests of social groups and strata, to the needs of the economy and the business, to public requests from both the central government and the regional authorities.

At one time, the doctor of physical and mathematical sciences I.D. Safronov [9], on the basis of numbers and structures, developed mathematical

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models of the activities of a research team, proposed several research team architectures, and also principles for the distribution of priority in models of collective creativity.

Author Evseev E.A. in his works [10-11] proposed a cognitive model of the research department. The model is based on information obtained in the course of social research of a real research and production enterprise. A number of parameters characterizing the state of the enterprise, and many target variables characterizing the performance of its work were obtained. The resulting fuzzy cognitive models are used to make control decisions to improve the performance and efficiency of work.

The problem of control a scientific school as an organizational system is considered in the work of D.A. Novikov [12], and the control of a scientific school as a dynamic multivariable system in the work of the authors [13].

Basically, in all works, the evaluation of the functioning of scientific schools is carried out by final results [14-17]. In this paper, it is proposed to assess the effectiveness of the control process of a scientific school.

II. The Concept of a Scientific School as a Multivariable Dynamic Control Object

The authors further adhere to the following notion: “A scientific school is an intellectual, emotional, value, informal, open community (structure, association) of scientists of different statuses, different levels of knowledge, developing a research program under the leadership of a leader” [18]. This definition is more suited to the assessment of the scientific school as a multivariable control object.

Let us highlight the three goal objectives that must be achieved in the functioning of the scientific school:

- training of scientific personnel and specialists to solve a problem or project execution;
- development and protection of scientific ideas in the form of patents, articles, reports, monographs;
- collective execution of a research problem or a complex project.

To control a scientific school as a complex dynamic object requires a high level of self-organization of the whole collective the form of three interconnected controlled subsystems. Each of subsystems seeks to achieve its goal for a specified given length of time and space.

The peculiarity of such organization is that each member of the collective participates in the functioning of all three subsystems, performing the function assigned to it, while transferring their knowledge to their colleagues, without in any way reducing their own stock of knowledge.

With such an organization of control, human factor may appear in the form of delay in the execution of the assigned function or decision-making, poor-quality performance of functions. Such will lead to a decrease the contribution coefficient of a member of the collective in the effectiveness of the entire collective.

Given this uncertainty and instability of changes in the parameters of a multivariable organizational system of control of a scientific school, it can be said with confidence that the problem of sustainability is becoming one of the main scientific problems of control. This problem will be further considered at the level of the mathematical model of a multivariable scientific school activity control system.

III. Mathematical Model of a Multivariable Scientific School Activity Control System

The structure of the linear multivariable scientific school activity control system is shown in Fig. 1. A feature of this model is that a collective intellectual resource is formed in the form of the sum of the decisions taken for each subsystem and their subsequent redistribution.

When developing the model, the following assumptions were made:

- the unit of time (1 s) may be equivalent to other physical units of time (hour, day, month, year, etc.) depending on the content of the task being solved;
- the length of time of the stable functioning of the system must also correspond to the actual physical segment of time, on which the goals are achieved;
- numerical values of the target equal to 1, or 100%, for each realized output coordinate corresponds to the volume of works which should be executed by the corresponding subsystem on the given segment of time.

The values of variables in Fig.1 have the following meaning: $x_i(t)$, $x_i^0\ (t)$ – adjustable and target variables, thus:

- $x_1(t)$ corresponds to the amount of work on training of specialists, scientific personnel, and to increase the level of their knowledge (*Vpk*);
- $x_2(t)$ – the amount of work to document the acquired knowledge, in the form of articles, reports, monographs, technical and design reports, techniques, technologies (*Vdz*);
- $x_3(t)$ – the amount of work on the project execuite (*Vvp*).

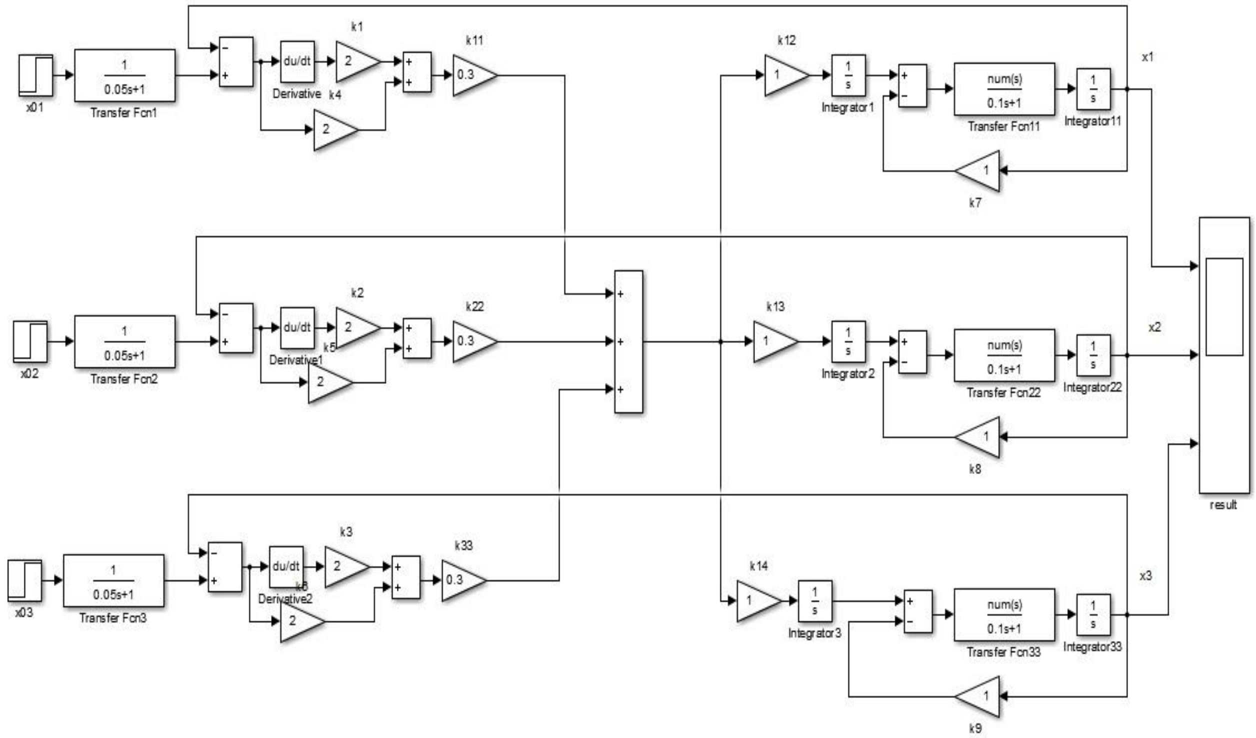

Fig. 1. The three-connected system of collective control of a scientific school

The peculiarity of this structure of multivariable control is that a collective solution is formed as a sum of control actions of all channels with the subsequent distribution (uniform / non-uniform) of a collective decision to the executive elements of all control objects of a three-connected system.

Fig. 2 shows the transient processes of reaching the goals in each subsystem with the synthesized parameters shown in Fig. 1.

It should be noted that when reducing the degree of damping in the control object, as well as increasing the coefficient of the open subsystem (k_{11}, k_{22}, k_{33}), the control process becomes oscillatory, which is not permissible.

IV. SYNERGY EFFECT IN COLLECTIVE CONTROL

Synergistic effect ("insight") is the sudden appearance of intellectual resources in the process of collective intellectual

interaction, which contributes to an increase in the final result, without requiring additional costs of material and technical resources.

To study the manifested synergistic effect, an element imitating "insight" (Fig. 3) was added to the model: the result of the collective control action is integrated and entered into the feedback of the channel of the third control subsystem.

As a result, a collective surge of ideas occurs in the consciousness of the collective, which over time reaches a certain constant value (0.7) (Fig. 4), which is distributed as some additional intellectual resource between the subsystems, increasing the final results of the subsystems that exceed the planned results by a certain constant value (0.2) (Fig. 5).

Consider a special case: in the presence of "insight" in the third channel, which gives an increase in intellectual resources to 1.3, then the efficiency of the applied resources through the first two channels (with a collective labor ratio of 0.5) decreases twice as soon as the desired end result is achieved. some excess, and the efficiency of the third channel (with the coefficient of collective labor 1) increases by more than two times (2.1) (with a feedback ratio equal to 2) (Fig. 6).

The results show that the contribution of collective labor to the functioning of the first two subsystems can be halved in obtaining the desired end results, and the results on the functioning of the third subsystem can be doubled due to the effect of "insight" in this system without additional input from the of material and technical resources.

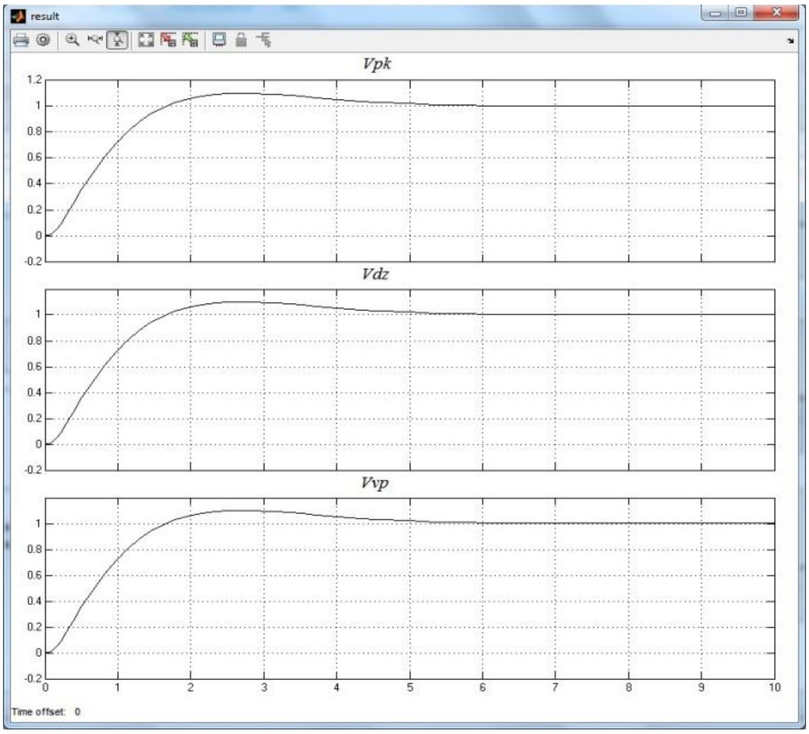

Fig. 2. Transition processes to reach goals

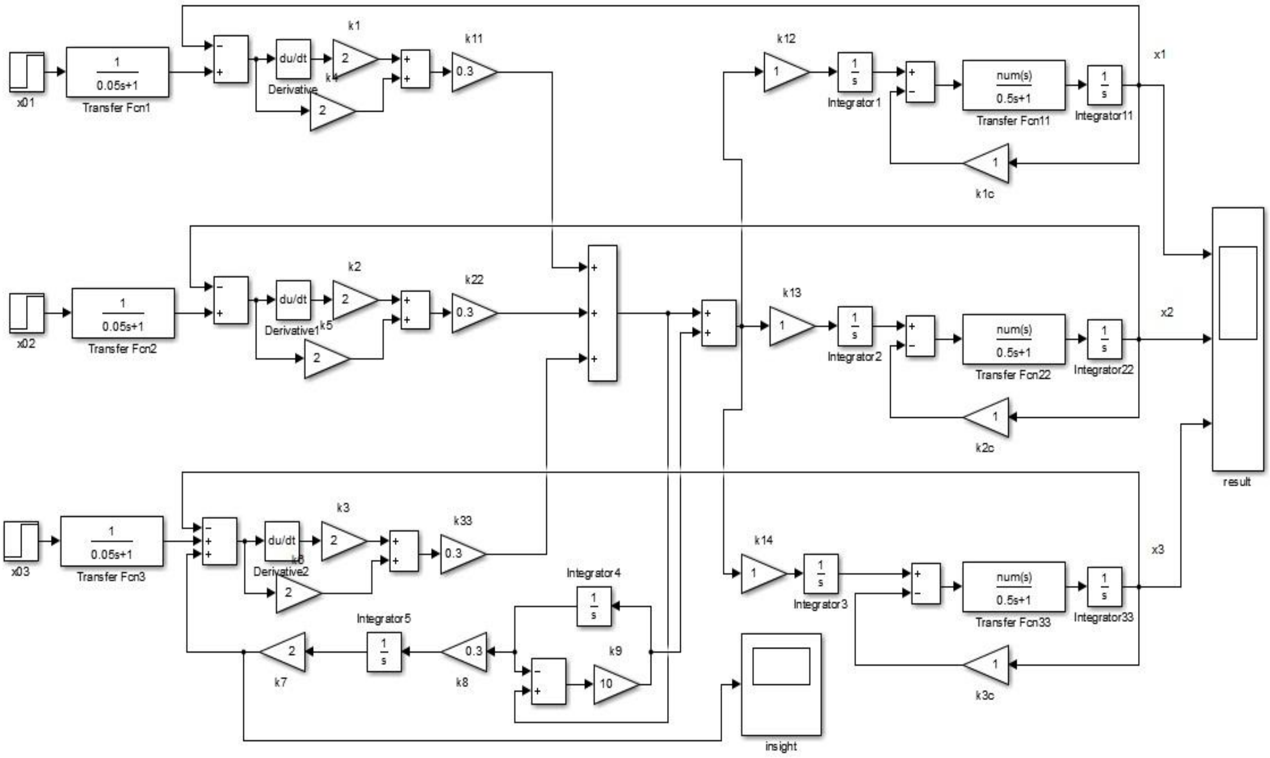

Fig. 3. Imitation of "insight" in the third channel

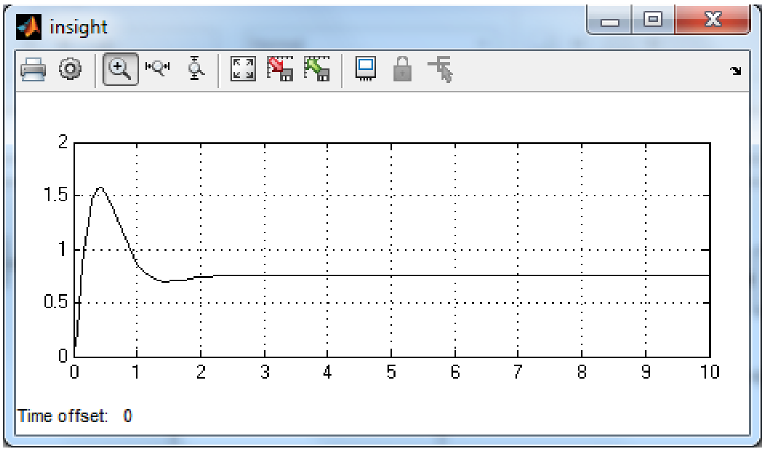

Fig. 4. “Insight”

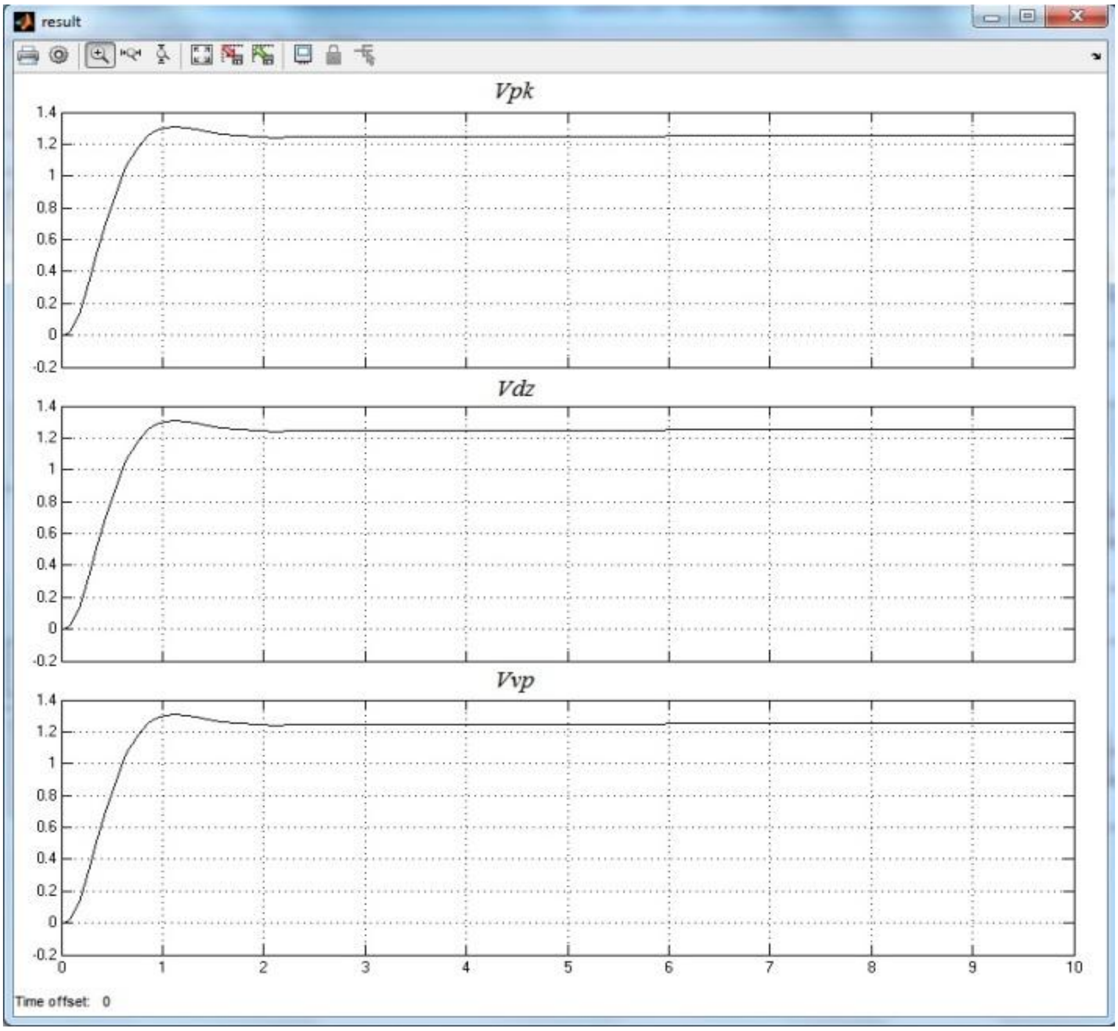

Fig. 5. Transition processes to reach goals

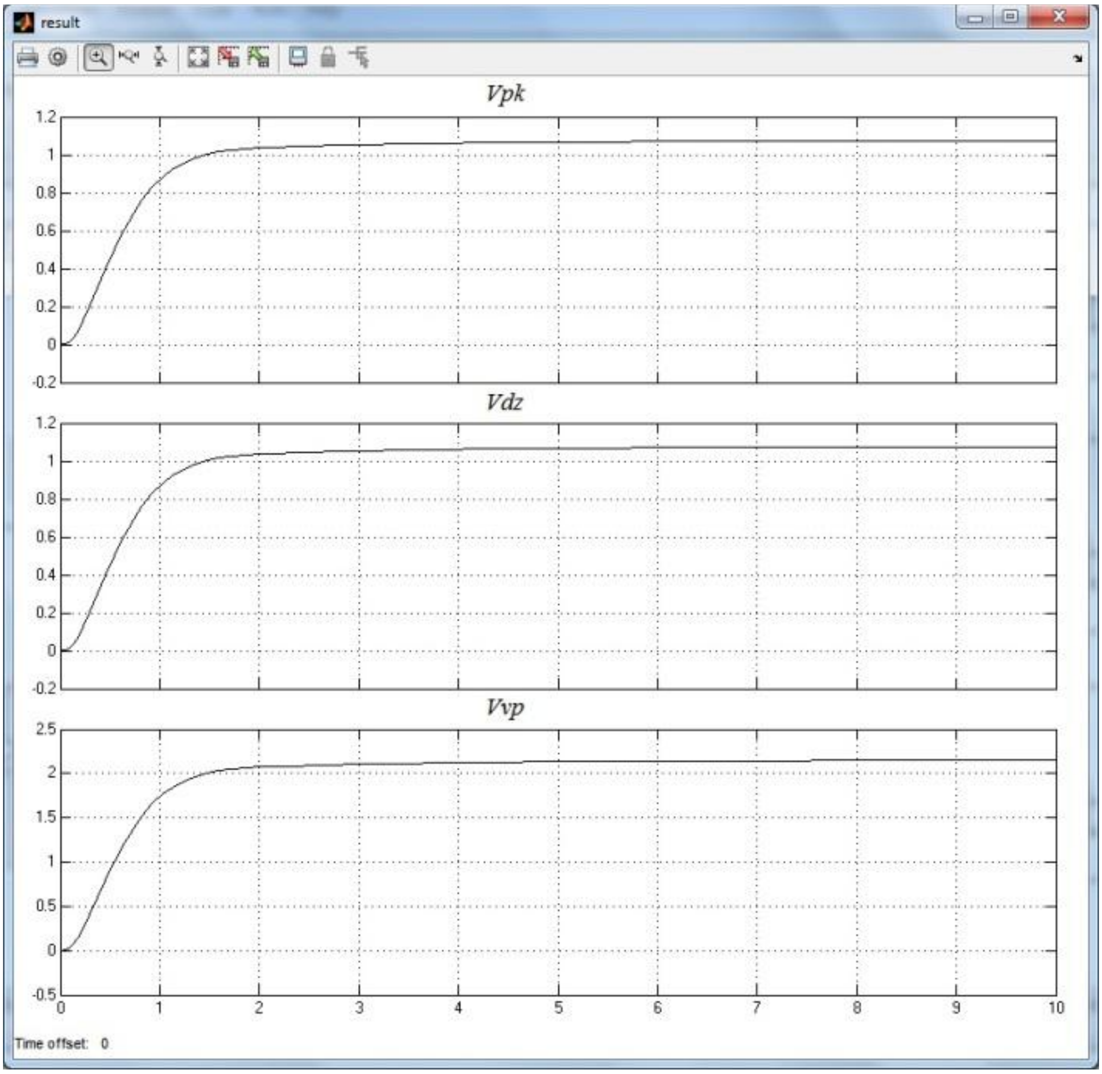

Fig. 6. Transition processes to reach goals

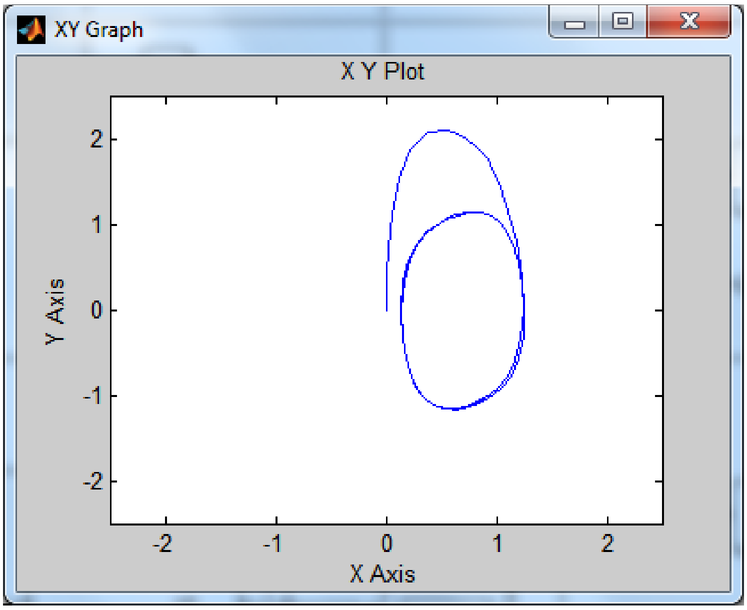

Fig. 7. Phase portrait

The appeared "insight" effect to a certain value of the feedback coefficient stabilizes the oscillatory process, that is, increases the stability of the system. In this case, a sustainable synergistic effect of collective intellectual interaction arises when making control decisions.

With an increase in the feedback ratio on the one hand, the effect of "insight" increases, and the system's sustainability margins fall.

You can indicate the optimal range of 2-2.5 value of the feedback ratio at which the maximum synergistic effect is achieved without loss of quality control system.

In case of equality of the feedback coefficient 5.5, the system is located on the border of oscillatory stability. And with a feedback factor of 8, and with a limit on the speed of building up the intellectual resource, the system has a self-oscillatory mode (Fig. 7).

Consequently, the desire to improve the effect of "insight" leads to instability of the entire system or to the appearance of self-oscillations.

V. CONCLUSION

The proposed structure of the collective control of a scientific school as a multivariable dynamic object allows one to achieve the required quality of control by synthesizing the parameters of the subsystems.

The structure of a multivariable system is proposed, in one of the subsystems of which, due to collective thinking, a synergistic effect ("insight") is formed, which is used as an additional intellectual resource in the control process, which increases the efficiency of the system, expressed in increasing the final result in all three subsystems without attracting additional material and technical resources provided in the plan.

The desire to increase the level of synergistic effect leads to loss of stability or to the appearance of self-oscillations in a non-linear system.

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