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Mathematical simulation of control system in Modal Vision Studium

Final Report by

Student Melnikov Konstantin

born on 08.10.1986

address:

pr. Dachniy, 24/2

Saint-Petersburg, Russia

Tel.: (812) 3721500

Saint-Petersburg State Polytechnical University
Institute of international Education Programs
Distributed intelligent Systems

Supervisor: prof. Yuri Senichenkov

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1. Introduction

Dear colleagues, theme of my work – Mathematical simulation of control system in Modal Vision stadium. In the given work I tell about one of tools of mathematical modeling – Modal Vision Studium. In the beginning it is told about history and structure of the given software product. The hierarchy of interaction of interfaces entering into it is described. Also workings out and the early languages of modeling used at its creation are described. After that there is a speech about various kinds of structural components – blocks, and the example of work of system is then resulted at the decision of three various problems. Last example is considered especially in detail, the mechanism of use of properties of object-oriented programming there is shown.

2. History and main features of MVS

MVS is the special language based on technology UML, the powerful tool for graphic modeling of difficult dynamic systems. UML – unified modeling language is a new direction in development of systems of the modeling, directed on unification of existing and future tools of modeling. Now there is a big problem of interaction of a various software, at transition from one environment of working out to another it is necessary to alter anew the created models, it is impossible will share results of the work with foreign colleagues since frequently in the different countries different systems are popular. For struggle against such difficulties also has been developed UML – object-oriented language of prototyping of difficult program complexes and computing systems.

What is the difficult dynamic system? It is large, multicomponent system, it is frequent with difficult communications. It can possess own hierarchy and depend both on external events, and from the internal. Because of it it can cardinaly change the behavior for very short time interval. Such systems also are called as hybrid and, as a rule, they hard give in to the mathematical description and modeling.

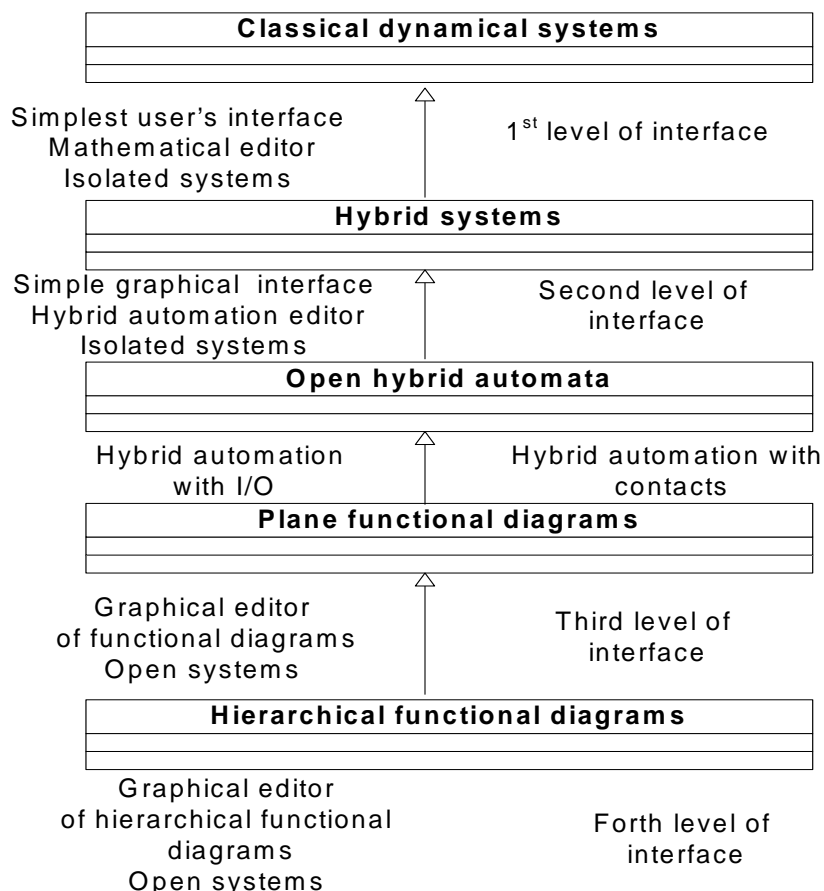
History MVS totals some years, all has begun with system MVS 2.1 in 1994. The given product develops actively and modernized. Since 2005 it is possible to get versions 5. Demos with are accessible to H.Nekotorye and on the Internet free of charge, but their possibilities are a little reduced. For example, restriction on the size of model is entered. We will consider, what workings out and concepts were included into a basis at creation of the given product.

First, it is one of the first languages of modeling SIMULA 67, developed Ole-Johan Dahl, Bjorn Myrhaug, Kristen Nygaard, and SLAM II by Alan Pritsker. These authors had been offered for the first time idea of creation of special models - classes for the description of objects with the similar properties, possessing internal properties and behavior. So there was a new approach to modeling of difficult multicomponent systems – the object-oriented approach. Also at creation MVS workings out were used:

- V., V. “Tools for modelling mixed continuous and discrete systems” (1975)
- Booch G. I. “The united modelling language for object-oriented modelling” (1977)
- Fillipov A. “Differential equations with discontinues right-hand side” (1985)
- Maler O. Manna Z. “A formal approach to hybrid systems” (1992)

Let's briefly review the hierarchical scheme of model in MVS. It is made by a principle from simple to difficult, i.e. we are beginning from the fourth level of the interface – Graphical editor of hierarchical functional diagrams? next we go up on third level of interface – graphical editor of functional diagrams. Further we create the open hybrid automatic machine which can be presented two kinds of blocks – with contacts and an input/exit. At the second level we create on the basis of hybrid automatic machines hybrid system by means of the graphic interface. It is second interface level. And now we pass on first level where with the help of simply and convenient interface and the mathematical editor the classical dynamic system so habitual for our eyes is created. So in general the hierarchy of construction of model in MVS looks.

MvStudium models



3. Different types of dynamic systems

Let's consider some kinds of dynamic systems which can be simulated in MVS.

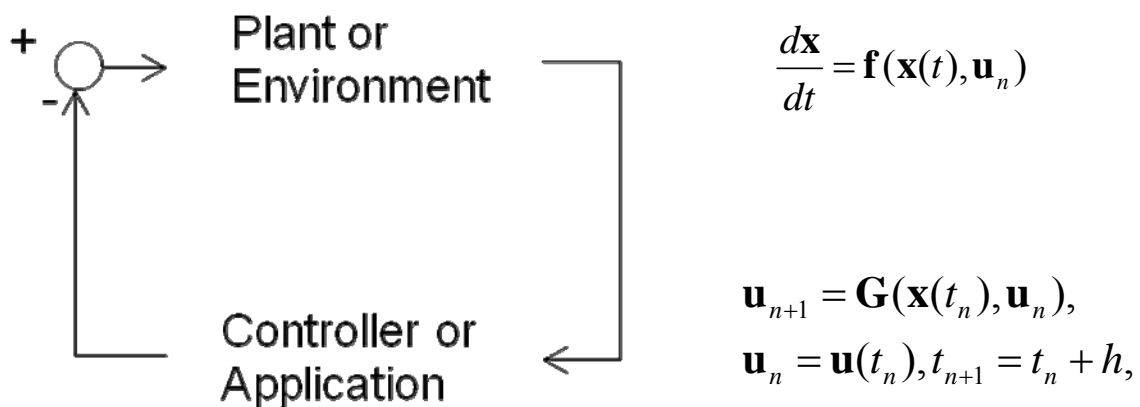
The first type – continuous systems. In their given classification it is possible to name the elementary but only because other pole are very difficult hybrid systems with discrete time. The given system of the differential equations., which right part is defined in all space of variables x and or is continuous, as well as its derivative, or satisfies to condition Lipshits's on all arguments, is called as classical dynamic system. x – set of decisions of the given system. t – an independent material variable she plays a role of continuous time.

$$\frac{dx}{dt} = f(x), x \in \mathfrak{R}^n, x(0) = x^0 \quad x = x(t; x^0)$$

In discrete models we cannot speak about the differential equations any more since there can not be a speech about derivative function when it depends on discrete time. In such models we deal with systems difference the equations. Directly discrete models cannot be processed by means of hybrid automatic machines, the special programming languages developed specially for work with discrete time are for this purpose necessary. However it is possible to try so to transform this model that begins to use probably hybrid automatic machines. For example, for synchronization of discrete processes it is possible to use continuous time.

$$\begin{cases} x_{n+1} = x_n \cdot \cos \alpha - (y_n - x_n^2) \cdot \sin \alpha \\ y_{n+1} = x_n \cdot \sin \alpha - (y_n - x_n^2) \cdot \cos \alpha \end{cases}$$

In dynamic systems can arise various and different scale processes. Difficulties of reproduction of such systems are obvious. Sometimes it is possible to divide fast and slow movements and to consider them separately then each of models has a characteristic time scale. However so to make it is not possible more often, and then it is possible to use such reception. The researcher solves, what processes in object to consider long, and what fast. Speed of fast processes is accepted by the infinite. Such processes are authorized to change value jump, unlike slow the indissoluble. We will consider a usual control system. The object of management works constantly, it is system of continuous time, and here an operating signal from a management contour comes periodically. It already will be discrete system.

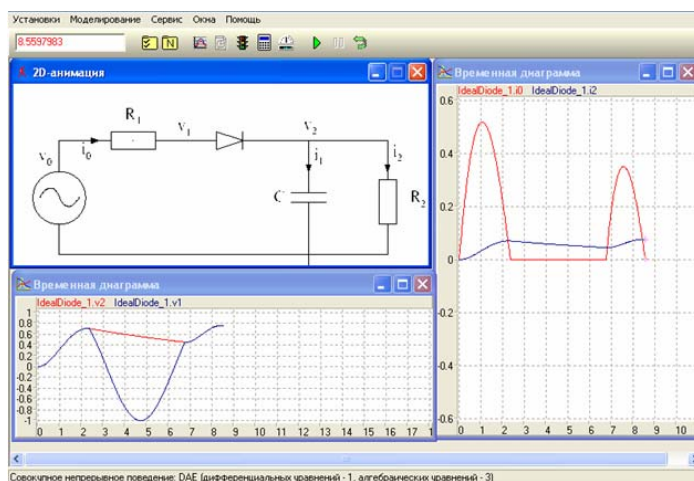


Then we will choose operating signals fast process, and object reaction – slow. Fast process changes in steps, and gradual reaction of object is traced constantly.

So there are models which name now hybrid systems. The term «hybrid systems» was used many years as a synonym of analogue-digital devices. For example, in dictionaries it is possible to meet a word-combination «hybrid computer» as the name of digital computers in which analogue devices are simultaneously used also. We will consider a body thrown under a corner to horizon, we will not only watch flight, but also to model elastic отскок from the earth. For this purpose we will allocate some special condition – a contact of a body of the earth, and it allowed to replace vertical making speed at the moment of its approach a sign with the opposite., then again we reproduce the set system with new entry conditions, and so again and again. It is possible to name the mechanism generating it the automatic machine, the hybrid automatic machine.

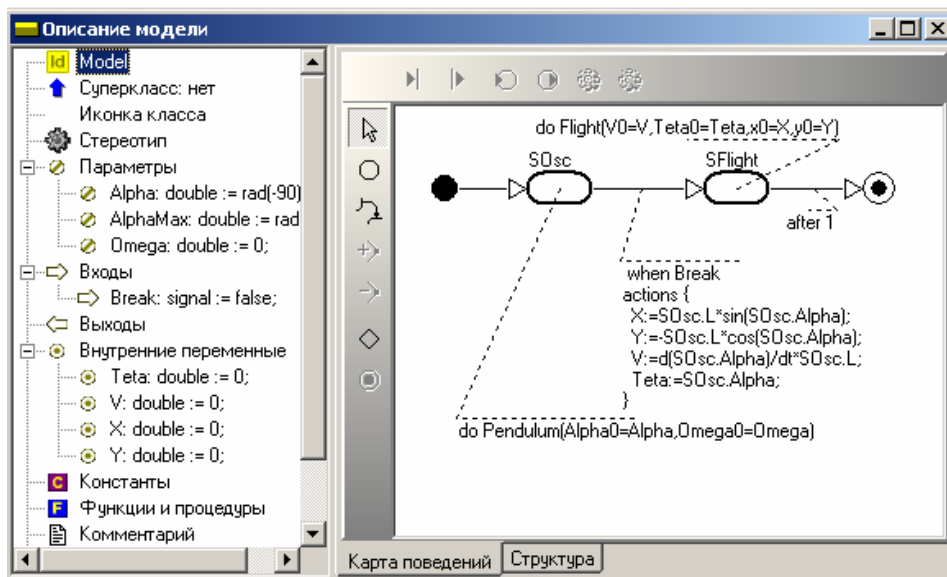
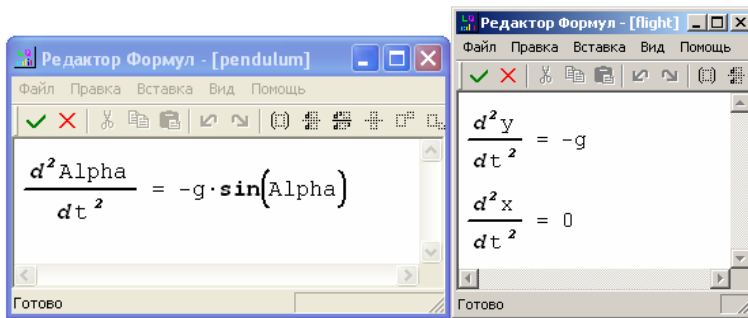
But the hybrid system cannot be constructed, not knowing, that such blocks and what they happen. Generalization of experience of modeling of physical, technical and natural systems allows to speak about two types of communication. If external variables are connected by the focused communications to these communications there correspond formulas in which to variables in the left part (inputs) known values of variables in the right part (exits) are appropriated. Information and physical communications in technical systems when special measures on an exception back influences are taken are directed. The structural component, all which external variables are focused, is called as the focused block or the block the input/exit. An example of the system constructed of blocks, the automatic control system is.

To nodirectional communications there correspond the equations in which it is impossible to specify required variables to the full analysis of all cumulative system of the equations arising at connection of blocks of model. A classical example of that approach is construction and modeling of electric chains. The blocks realizing such principles, are called as nodirectional, or open blocks with contacts. In this example the scheme of the ideal diode which is difficult enough for realizing in other software products – all business in difficult behavior of the diode which sharply changes the condition is constructed. But as we already know, for hybrid automatic machines it not a problem.

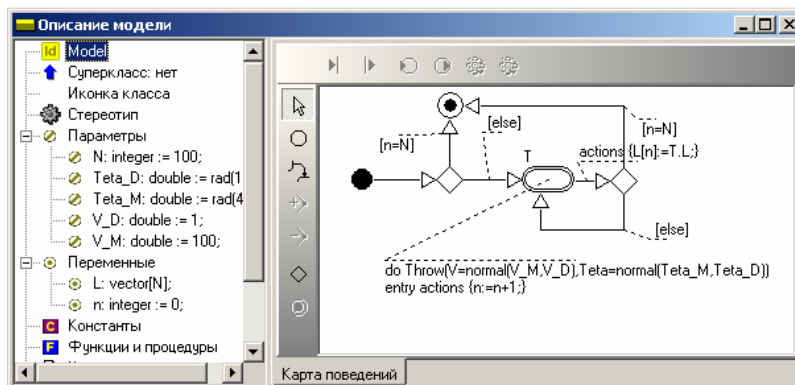


4. Examples of modeling

Let's pass to consideration of examples of modeling of difficult hybrid systems in MVS. The first example is «breaking pendulum» where cargo comes off from cord in any point of a trajectory. In the graphic editor it is possible to see, that 2 automatic machines are created. The first models rocking of the whole pendulum under the simple law of a sine. But, as soon as cargo comes off, business is entered by the second automatic machine describing movement of cargo as a body, moving by gravity.



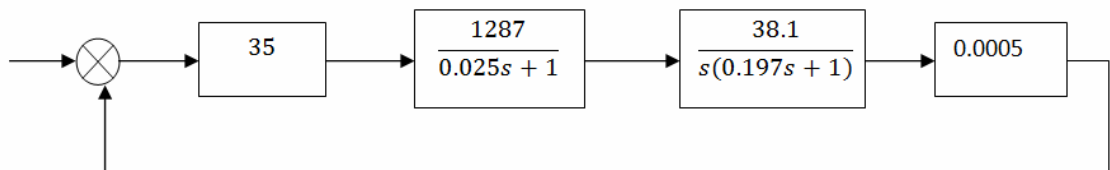
The following example about possibility of statistical tests which can be spent by means of a card of behaviors. Here the body throw under a corner to horizon is modeled, and also the corner size is established at which the maximum range is reached. By means of the artful scheme we build the elementary algorithm with the hybrid automatic machine in a basis which some times will throw a body under different corners to horizon. At first we set the equations in the first window, necessary for creation of the hybrid automatic machine with zero entry conditions, and then we include it in algorithm.



5. Modeling of real complex dynamic system

Now we will pass to the most interesting example - to modeling of real dynamic system. We will consider a drive of management which is used for example in the plane. This system consists while of four elements:

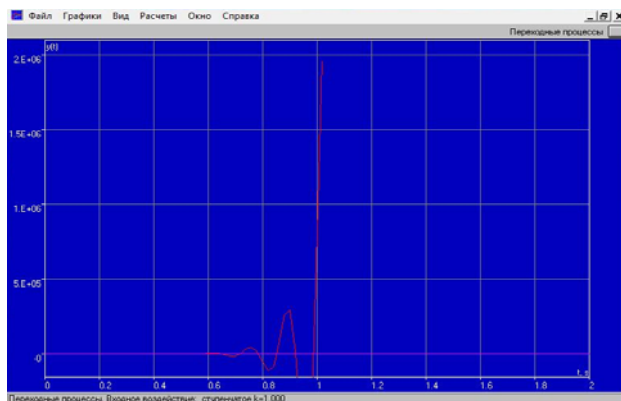
- Sensitive element which accepts a mismatch signal
- The amplifier which strengthens an operating signal that its tax on the engine.
- The dysphasic asynchronous engine
- Reducer, reformative rotation of a shaft of the engine in turn on small degree.



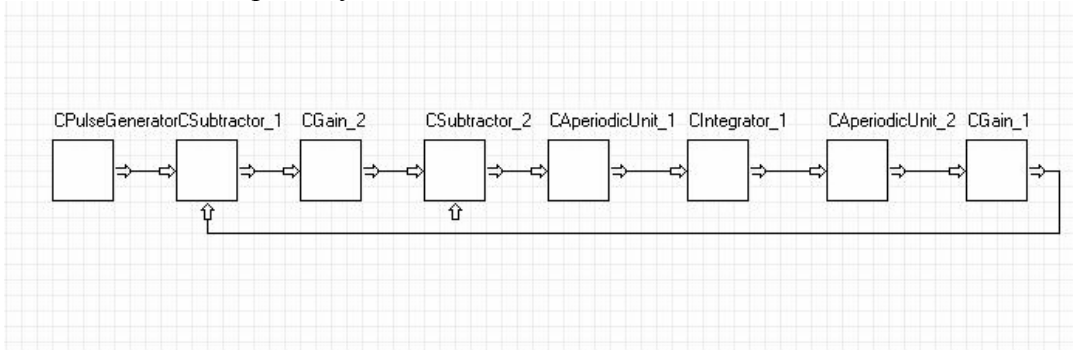
It is classical configuration of systems of such class with a negative feedback. All elements of the given system are absolutely real, exist in practice. They have the corresponding transfer functions shown on this slide. These transfer functions are a little simplified, the consequence of fluctuations of a shaft of the engine in a reducer, therefore its characteristic such simple for example is not considered. Nevertheless all these transfer functions are received on the basis of the real technical characteristics of this the element which has been written down in their characteristics sheets. But given system for the present not full, it does not suffice correcting devices. They will be added later for now we will look as the system behaves not corrected.

Modeling and the analysis of the given system is spent by means of two tools – already known to us MVS and small special package CLASSIC 3.0. It is a package already enough old, but its charm that it is narrow специализирован on the decision of such problems. Let's look at process and results of modelling.

Let's begin with program CLASSIC. This environment in the simple graphic interface our scheme is made of blocks of type an input/exit, communications between them are then spent. Then each block separately is edited – in fractionally-polinomial kind transfer functions register, the input and an exit of all system are appointed. After giving of values to all blocks we give a step individual signal on a system input and we receive result. The received transitive characteristic says to us, that the system works astably, such result leads to its breakage.

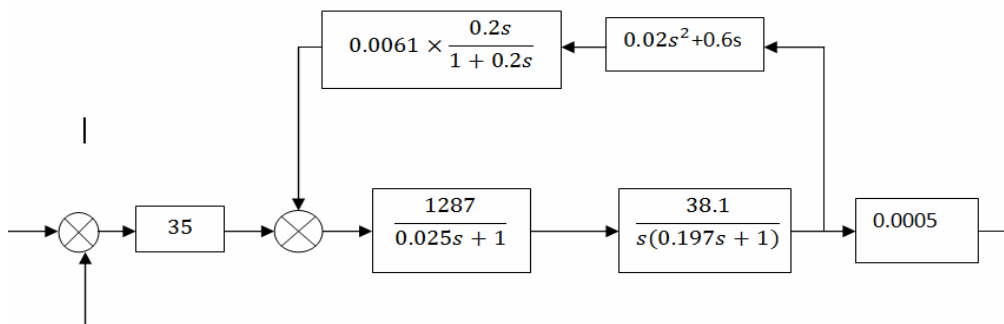


Now let's model the same in MVS. Here already there is a special library with a set of standard blocks. Here there is аperiодическое a link of the first order, the integrator, differential unit, an oscillatory link, and also generators of various entrance signals. We will make with their help our system – the scheme turns out such here.



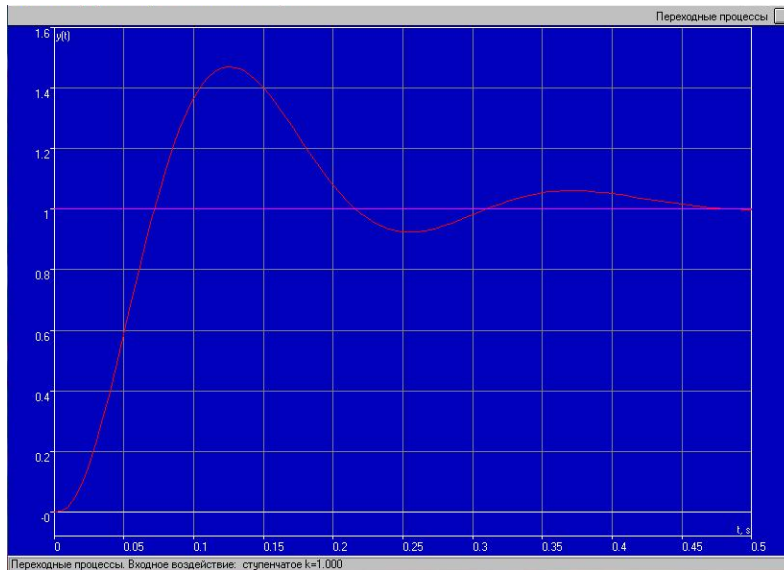
It seems little bit more difficult previous, made in CLASSIC, but the signal generator in an explicit form here was simply added, and the engine has been set by two typical links. We establish necessary values of our blocks and we start model. We receive this characteristic. Results of work of two programs coincide – the system is not balanced, therefore in half-seconds after the beginning of work it fails.

It is necessary to create the device developing correcting influence and reducing the transitive characteristic of system to steady position.

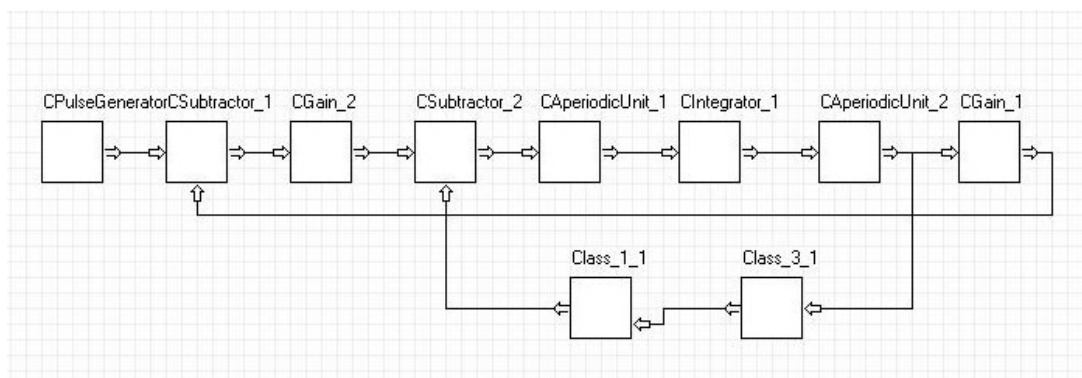


Here the scheme of the corrected system. Not to block up this work I do not show process of creation of the device of stabilisation. The story about this work done by me can occupy not one hour. For construction of this device I had been used a method of construction of the desirable logarithmic peak characteristic, by the offered Russian scientist Besekersky. The given type of correction is called as parallel correction of a site of system. The additional negative feedback, covering the amplifier and the engine is for this purpose created. To the engine it is connected тахогенератор – the special device, reformative speed of rotation of the engine in pressure. I.e. it is the gauge of angular speed. It has the following transfer function. Devices of such type are called as a forcing link of the second order. And to it we include the calculated correcting device with such transfer characteristic. We will be convinced of working capacity of system.

To begin with we will check up this system in CLASSIC. We add to our scheme two more blocks, we set a step individual entrance signal and we teach result! Now the picture has strongly changed – the system does not break, and converges gradually to size of an entrance signal, and very quickly – all for half-seconds. The size of reregulation does not exceed 25 %, oscillation systems also is low. Fine result.

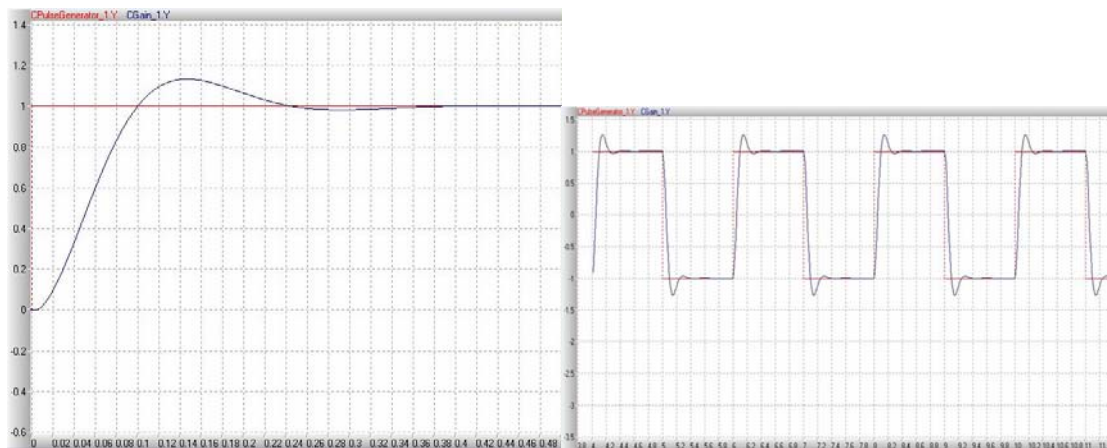


Let's simulate the same corrected system in MVS. But here there is one complexity – in library there are no the typical links necessary for us. But it is not terrible – in MVS it is possible to create the blocks of different types with any characteristics, to keep them and to use in other models as elements of the general library. Now I will tell, how it is possible to create easily the own block in MVS on a link example of tacogenerator. To begin with we choose system type to which the block – continuous belongs, then we choose elementary structure and open type of the block that there was a possibility to create inputs and exits. We accept these installations and we pass to the block description. Analytically by means of return transformation Laplas's we receive from transfer function tacogenerator the differential equation with which works MVS. It turns out the second order, but for this program it not a problem. Further we write down parameters and we appropriate it values 0. In model we can already change them to the necessary. Well and at last we appoint X to an input, and At we submit on an exit. Well, it's done! We can insert our block into model. Only do not forget it to keep. We make the same work with the correcting device and we receive the working scheme of the corrected system in MVS.



We start our model. We set a stop condition - the system will stop in half-seconds. What do we have? Transient converging, system works perfectly! Reregulation of only 15 %, system is stabilized all for 0.4 seconds is very good result. If we disconnect now time restriction we will see such schedule. Such continuous operating mode corresponds to real conditions, for example

we by turns turn to the right and to the left. Our corrected computer-controlled system copes with the given problem.



6. Conclusion

In summary it is possible to tell, that the sphere of applications MVS is very wide, and the considered examples far not a limit of its possibilities. Now there are very few systems in which it is possible quickly and to create difficult multiple hybrid systems conveniently. Pleasant addition are interfaces for two- and three-D measured graphic display of the received results. Having simulated system, we can draw it in a three-dimensional kind, adhere drawing coordinates to variables and receive the moving three-dimensional picture displaying received results. Especially pleases possibility directly to set the differential equations of the first and second order, that considerably facilitates and accelerates work. On last example could seem what easier to work with transfer functions, and their transfer in the differential equations only distracts. Actually it not so. If to consider, that these transfer functions have initially been deduced from the differential equations it becomes clear, that such approach considerably simplifies modeling.