Terminology

Taking into consideration modern tendencies of simulation the real world, from our point of view, can be presented in the form of four main components: channels, ports (streams), objects and structures. Currently, such terminology is not a standard; therefore those who are interested can appeal to the well-known books. Taking into account that this work is not a monograph, but only the author's conception about simulation we will write only about this conception.

During the development of the program MODEN we used both terminology that is used in energetics and taken from programming, automation and object-oriented design. We understand, that potential user of our program can be frightened off, firstly, by unusual terminology, and, secondly, by given material. Therefore we make to you in advance our apologies. But if you know terminology of the subject you know 50% of the subject. Will you believe it or check it?

The energy system structure that is made according to the organizational principle is presented in fig. 3.1. We will begin the study with the main notion of a program - object.

Object is an element of the lowest level of a power system which can be both consumer, and energy source. If we claim, that "heating coil" is an object, and then we understand that we are not interested in the device itself i.e. in elements it consists of. If we will decide to examine "heating coil" more deeply we will discuss such objects, as tube and shell side, calling them objects. In this case "heating coil" turns into the structure.

Structure is one of the elements of the power system that consists of objects and exists under its certain laws and also has its own material embodiment. Very often structure includes the other structures. There are energy connections between the objects. Such connections represent concrete type of energy flows. It is clear, that connection (stream) of a certain type cannot be brought into intentionally taken object. Thus, "heating coil" will not take compressed air. The notion of port is used to show what kind of streams can be taken in by the object.

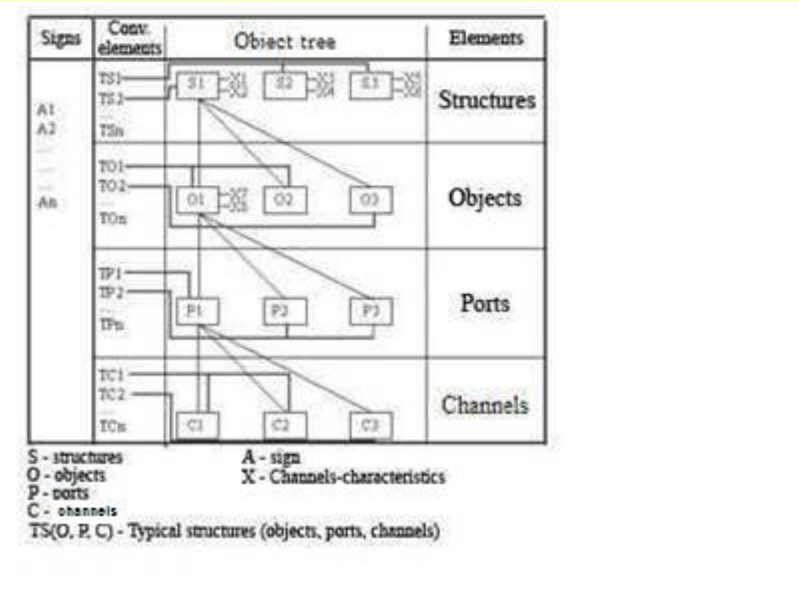

Fig. 3.1. Scheme of nesting arrangement in the program MODEN

Port is an element in the enclosure of the object through which the stream passes from the environment. Each port can take only one type (sort) of stream. Ports of the object are marked. Thus the object "heating coil" has four ports. Ports 1 and 2 are used for the heating medium - water passing and ports 3 and 4 are used for the heating medium - air passing (it is clear, that marks are fixed by the user).

Each stream is characterized by a number of parameters that are used as channels in the program.

Channel is the smallest element that is used in a model construction. If we take such stream as water it can be characterized by the following parameters: temperature, mass flow rate, pressure, specific heat, etc. If at simulation we use any stream it does not mean yet, that we should work with all its channels. All depends on those tasks that we are ready to put before the model. Redundancy of defining channels leads to the complication of model and difficulties of its development.

Structure, object, port, channel are all system elements. There is a concept of the typical element in the program.

Typical elements are such elements on the basis of which we will make all other elements of the model. There are following typical elements in the program: channels, streams (ports), objects and structures. Why is it so? Is it not enough to have only typical channels? It is possible to answer this question in the following way: «The higher level of typification (from channel to structure), the easier to simulate real objects». One may say that it is optimally to have such typical structure as enterprise in the base that we are going to simulate now. Each element in the model has an analogue of a typical element. It is necessary to change a proper typical element if you want to make changes in any element. But there is one problem in the work with large typical structures or objects - all the typical elements are "empty". What does it mean «empty elements»? And again let us imagine a heating coil. Let us remember that it has four ports, thus it has suitable channels as well. But what determines the dependence between channels (parameters)? It is only physical rules (formulas) inside the objects. Thus as we can see there are no typical elements inside. These formulas are kept only in the templates of objects and structures.

Templates are small energy system models. Templates are made on the basis of typical elements, but they have rules (formulas) that describe connections between channels. It is more convenient to use templates than typical elements. Typical elements should be “filled” additionally with the rules (formulas).

Rules (formulas) are dependences inside the objects that belong to the channels and allow calculating values of the channels. The rules can be simple, and they are determined by one formula, for example, the equation of the heat transfer through enclosure

$$Q=\underset{.}{T}(U*A)w*(Tin-Tout), \qquad (3.1)$$

and also rather complex rules, using logical expressions, numerical differentiation and integration. In the rules (formulas) we almost always refer to values in the other channels (of its own or other objects). These references are called information (channels).

Information channels are channels that do not belong to the streams used for energy transfer, or any material substance. Such channels are used only for connection between parameters in the formulas. These channels do not require ports. They can be created in any quantity. They do not require typical channels for accordance. The only thing we need is to make connection between the parameter in the formula and the necessary channel of energy flow, or between the channels of object (structure) characteristic.

The characteristic of the object (structure). Characteristic is a special channel, that exists in the object (structure), and that has certain attributes (parameters, properties) of the object (structure). These attributes did not find its reflection in channels of ports. The following attributes are used as characteristics: name, type, mark, area, volume, etc.

How to detect the necessary channels without sorting them out one by one? How to group the objects into the structures? How to make a report only about necessary elements of the system? That is why we have such notion as an attribute in the program.

Attributes are labels that are assigned to the elements of the system, which also help to choose the elements marked with corresponding attributes while sorting them. The user chooses attributes from the base of typical attributes. Attributes belong to the elements of model, except such attribute as class which belongs to the typical objects.

To distinguish the typical structures (objects) from the structures (objects) of the model, the last of them we will name as unit.

Power system work occurs in real time, in this program it is calendar time. In contrast to that the work of the system model occurs, in the so-called, simulated time. Calendar time is rarely used in the program. It is usually used when it is necessary to impose the information from real system to simulated one. It is done, for example, at the check-for-adequacy stage.

3.2. Realization of physical laws in the program

Fundamental laws of physics are presented in the section 2. Now we will show how these laws of physics work in the models, namely, in the program MODEN.

Each simple law is connected with any substance transfer (matter, energy or information). Substance transfer is possible only at interaction, at least, of two objects. If there is no cooperation the substance transfer is impossible. Substance transfer is impossible at non-interaction. The substance is characterized by a set of parameters (channels) and in terminology of the program MODEN it is called as port. It is necessary to connect two bodies in case of heat transfer by conduction. If the bodies have different temperatures then heat conduction is observed. There is a question. If the body is solid, then three will be no conduction? The question is that any solid body in the program should be presented as a body consisting of smaller finite-dimensional elements. For those who know how to solve physical problems by the method of finite differences, it will be clearer. Otherwise the solid body in MODEN will be presented as an object with lumped parameters. And we cannot calculate the distribution of parameters, for example, of the temperatures in various points of a body, but only average parameters by volume.

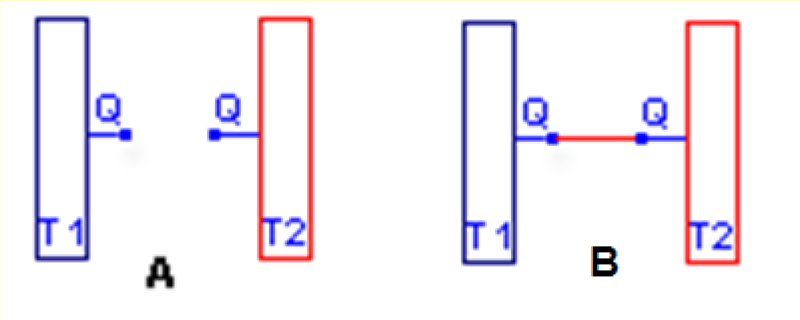

Fig. 3.2. Heat exchange by conduction at the connection of two plates: A- before the connection of ports, B - after the connection of ports.

There are two identical thin plates (from one material) shown in the fig. 3.2A. Its thickness is **δ** and it has identical surface of contact which is dA. One plate has initial temperature T1, and another one - T2 (let T1> T2), so let us name them, accordingly, T1 and T2. Each of the plates has only one port for heat exchange by conduction - Q. It can be presented, as heat-insulating boards from each side, except one, and there is no radiant heat exchange or it can be omitted. We will connect these plates. In terminology of the program it means, that it is necessary to connect Q ports. There are ports after the connection shown in the fig. 3.2B. Heat conduction starts working and it means that the heat flow is observed and it is

$$dQ=T*dA*dT/dx, \tag{3.2}$$

where T – thermal conductance coefficient of plate material, W/(m*°C),
dA- surface area of contact through which heat exchange is transferred, m^2,
(T1-T2)/δ – temperature gradient, °C/m.

Q port of each plate has only one channel – heat flow and its value can be determined by the equation 3.2. Until two ports were connected, it was possible to write the formula 3.2 in each of the channels, but it did not work because the temperature T2 for the channel of the plate T1 was not indicated, and for the plate T2 the temperature T1 was not indicated as well. It became possible to indicate these temperatures only after the connection of ports.

We have examined only two connected ports. In a real object it is possible to find much more of them. Moreover port streams run in parallel. It means that they run simultaneously and cannot interact.

Let us look at the second simple example and take an object - PIPE-01 (fig. 3.3) where **water-heating medium** runs. It is necessary to create pressure difference to make water running. Let inlet pressure of water in the pipeline is P11, and outlet pressure is P21 and it can be determined by the equation (3.3)

$$P21=P11-S1*G1^2 \tag{3.3}$$

where **S1**- characteristic of hydraulic resistance of pipeline 01,
G1- mass flow rate of heating medium through a pipe (it is specified!!!).

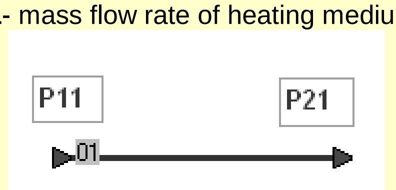

Fig. 3.3. Pipeline – code 01

Let us connect our PIPE-01 with the PIPE -02 (see fig. 3.4). It is clear that inlet pressure of the PIPE -02 (P12) should be equal to the outlet pressure of the PIPE 01 (P21). At the connection in the program MODEN the value of pressure P21 will be automatically transferred to the pressure P12 without mentioning it additionally. In this case the passage channel of water inlet port in the window “Formulas” cannot be edited (usually marked blue in the window "Formula").

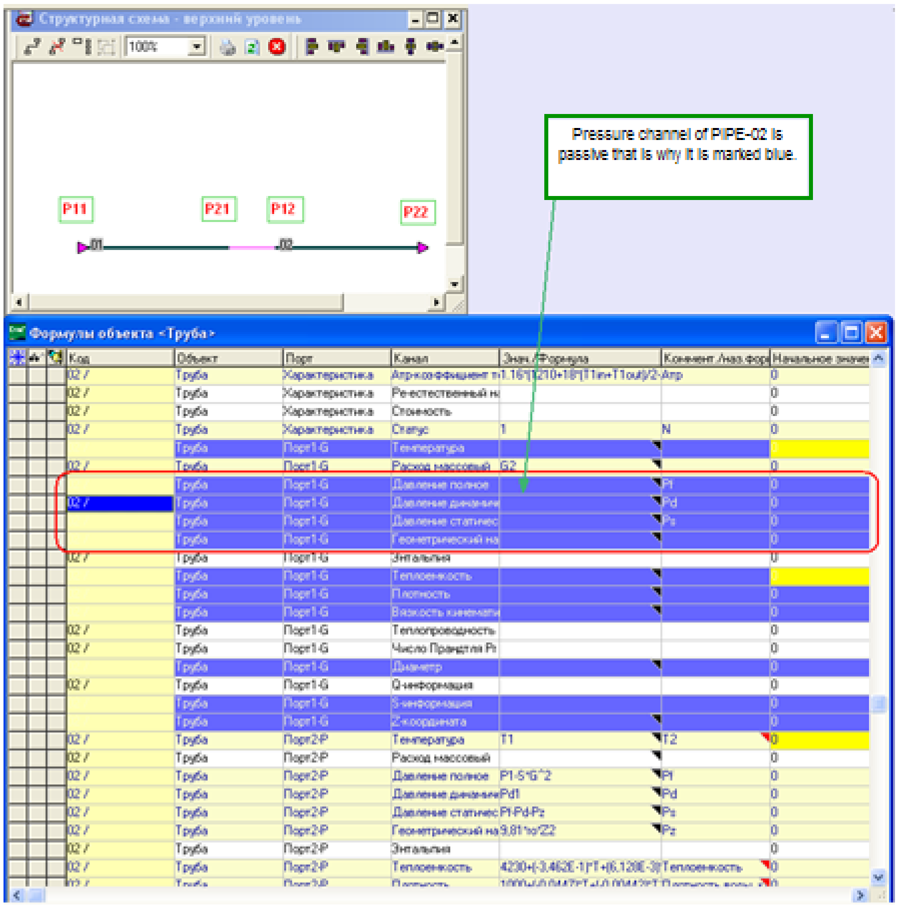

Fig. 3.4. Connection of two pipelines

Water outlet pressure from the PIPE -02 will be

$$P22=P12-S2*G1^2. \quad (3.4)$$

where **S2**- characteristic of hydraulic resistance of the pipeline 02.

Thus, we showed how pressure transfers from inlet port of one pipeline into outlet port of the other pipeline. The same happens with the transfer of other parameters.

We will name passage channel of water outlet port of PIPE -02 active because its value is determined by the formula (3.4). Passage channel of water inlet port of PIPE -02 we will name passive as it gets values of pressure from the adjacent channel of PIPE -01.

Let us suppose that passage channels of water inlet and outlet ports from PIPE 01 are passive. In this case, according to the formula (3.3), the water capacity through the pipeline will be

$$G1= ((P11-P21)/S)^{1/2}. \quad (3.5)$$

Such object **forms the flow rate**. In the description of the formula (3.3) it was underlined that the flow rate **was specified**, it means that it came from without. It is interesting that values of pressure and flow rate parameters can be transferred both downstream and upstream of the heating medium.

The flow rate and pressure are connected parameters, and it imposes additional complexity on hydraulic systems, at the same time the temperature is not connected directly with any other parameter, though many of them depend on it. The temperature is simply transferred from the inlet channel of water into the outlet channel. If heat losses in the pipeline are taken into account the outlet temperature of water is a little bit lower, than inlet temperature in the pipeline. Unlike the parameters of pressure and flow rate - the temperature is transferred only downstream of the heating medium.

But not everything is still clear about formation and transfer of the parameters in the power system. It might be clear in future and so far we are discussing with you what we have understood by ourselves.

3.3. Calculation in the program

The numerical solution of the systems of the nonlinear non-stationary algebraic equations is realized in the program MODEN. Though all the systems TGSV work in the continuous space and in computer the same processes are realized in discrete space. It means that we can fix the system state only at certain instant of time. For example, if we began the report of system work at instant time t0=0, then the following value of time will be $\tau_1=\tau_0+\Delta\tau$, where $\Delta\tau$, - account interval inside the program. Let us note that the program allows to use any account interval, at least 10^{-3} s. As the moments of time are discrete, it is very convenient to indicate them with the help of ordinal numerals 1,2,3…n…, i.e. τ_0, τ_1, τ_2,… τ_n,…

The solution of the systems of the nonlinear non-stationary algebraic equations can be done in a variety of ways. However in the program MODEN is used one of the most simple ways - Seidel method. And this method is used not because of the author's whim, but because it is the most natural method, i.e. corresponding to the real nature of the case.

In contrast to well-known package Simulink the approach connected with the use of blocks, describing various mathematical procedures and functions is not used in this program. In the program is used the approach connected with the use of templates of the objects and structures and introduction of mathematical procedures and functions inside these templates. It is, of course, clear. There is no mathematical block that carries out well-known procedure for the heating engineer (see section 2)

$$Q=U*A*(T_{in}-T_{out}), \qquad (3.6)$$

But there is a simple object - an external wall, where exactly this procedure is carried out. We keep this note not as a separate template, but inside the object « an external wall » for describing one of the port channels "heat".

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