The exceptional complexity of the technological structure of the contemporary national power industry and the interconnections between individual power units predestined its division into a number of systems. The unified national power system standing at the upper hierarchical level is divided into five basic specialized systems which together guarantee the national economy all forms of energy and fuel: an electric power system, oil, gas, and coal supply systems, and a nuclear power system presently being formed. These systems are divided into appropriate systems of individual regions of the country. The ultimate elements of large power systems are businesses — power producers and consumers [1]. In turn each power producer is a complex system which includes a large number of units of various types of power plants joined by physical, technical, and transport ties. It is expedient to represent each such complex system as a series of hierarchically coordinated systems.

Four hierarchical levels are generally distinguished in thermal power systems: thermal power plants, power units, groups of plant elements, and plant elements.

The final elements of the hierarchical structure of a thermal power system — the plant elements — must be detailed further for the study of individual phenomena, processes, and structures. These investigations are performed at lower hierarchical levels, i.e., at the level of physicotechnical systems of parts of plant elements when the problems of the development of thermal power become problems of mechanics, thermal physics, physical metallurgy, and other related disciplines [2, 3]. The importance and complexity of the problem of the optimum design and long-term development of thermal power systems of various types are obvious. Nuclear power plants are no exception. Figure 1 shows the system of informational interconnections of a nuclear power plant arranged according to the hierarchical principle.

The external input data result partly from optimizing the power and economic systems at a higher level; the nuclear power plant is one element. The external input data are obtained partly from predictions and expert estimates. The internal input data include a description of the laws and characteristics of the flow of technological processes, physical properties of the working media and coolants, and characteristics of different kinds of plant structures. Descriptions are given of the constraints imposed on the parameters and characteristics of the structures. The input data also include lists of design layout types for power plant equipment and variants of the form of its process flow diagram (or the conditions of their formation).

The information obtained by solving the optimization problem includes integral and discrete characteristics of the form of the process flow diagram of the power plant, continuously variable thermodynamic and flow rate parameters of the energy carriers, discrete characteristics of the types of structures of units and basic plant elements, and continuously or discretely varying structural parameters of plant units and elements. In addition to its direct use to establish optimum parameters and characteristics of a nuclear power plant this information also appears as internal and external feedback data. The internal feedback data determine the direction of further development and improvement of investigations leading to a lower step on the hierarchical ladder, i.e., to the level of physicotechnical models of individual phenomena, processes, and structures. The external feedback data link includes optimum technical and economic indices of the plant for various conditions of its use, technological, weight, and structural characteristics of units and elements of the equipment of an optimized plant, characteristics of surges, industrial wastes, heat release, and other factors which describe the effect of the power plant on external systems and the environment.
In addition to the indicated streams of external and internal data there are direct and feedback streams of so-called intermediate data circulating within the system of mathematical models considered. These data streams contain information on optimum values of parameters obtained by solving optimization problems at various hierarchical levels within the power plant.

This hierarchical structure of intermediate data makes it possible to organize a two-step optimization cycle - downward and upward. In this case there is taken into account the decreasing influence of more detailed information on the refinement of overall optimum solutions, and hence the possibility of decreasing the volume of data exchanged.

The intermediate and sought for data can also be used to investigate the content of the models and the structure of the interconnections between them, i.e., to construct an optimum system of mathematical models. In this case supplementary cycles of interconnections arise between the system of models and the sources of internal input data.

At the present time a qualitative solution of the problem of optimizing the values of the parameters, the form of the arrangement, and the design of an atomic power plant are impossible without the extensive use of mathematical modeling and a computer, leading to a solution whose suitability depends on the extent to which the time of completion and the capital outlay are taken into account.

Studies of the problem under consideration have been directed toward developing a theory and methods of a comprehensive thermodynamic, technical, and economic analysis and complex optimization of a nuclear power plant based on mathematical modeling methods and the solution of complex experimental problems and the use of a computer.

So far the following [2–5] have been developed: theoretical bases for the construction of mathematical models of various types of nuclear power plants for complex calculational studies; methodical bases for the use of nonlinear mathematical programming and computers for solving the power plant optimization problem; practical ways of applying the methods of mathematical modeling, nonlinear mathematical programming, and computers to determine ways of increasing the economy of various types of atomic power plants by the choice of optimum neutron, physical, thermodynamic, cost, and structural parameters, and also an efficient form of the process flow diagram.

The mathematical formulation of the problem of the complex technical and economic calculation of a nuclear power plant of a given form can be written as follows:

$$Z = Z[X_g, Y_g(X_g), G]_{E_0}$$

for

$$f_k[X_g, Y_g(X_g)]_{E_0} = 0;$$

$$Y^*_g < Y_g(X_g)_{E_0} < Y^*_g;$$

$$F^* < F[X_g, Y_g(X_g)]_{E_0} < F^*_g;$$

$$X^*_g < X_g < X^*_g,$$

where $Z$ is the target function, $X_g$ and $Y_g$ are sets of independent and dependent plant parameters; $G$ is a set of parameters depending on the form of the plant design; $E_0$ is a set of characteristics of given external factors; $k_g$ is a set of balance equations for all plant units; $F_g$ is a set of technological characteristics of the plant units describing the restrictive conditions; one and two asterisks denote respectively minimum and maximum admissible values.