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GENERAL ISSUES OF POWER INDUSTRY

# Half a Century of Systems Studies into Developing the Power Industry in the Soviet Union and Russia: What Next? (Review)[1]

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**Abstract**—The centenary of the adoption of the GOELRO Plan[2] marked this year is a remarkable date for power engineering. Fifty years later, the comprehensive energy method used to develop the plan became one of the bases of the methodology for system studies into the development of the power industry. The preconditions for the emergence of this methodology are considered and its basic scientific, methodological, and applied results are characterized. The latter are represented in chronological order over two stages of the socio-economic development of the country. During the Soviet period, the theory and basic methods and models were created for system studies into the development of the fuel and energy sector of the country, its industries, and regional subsystems (1970–1980) and their application to the long-term panning of the development of the Soviet Union's power industry began (1981–1991). These preconditions facilitated the formation of procedures and apparatus for managing the development of the power industry of the reformed Russia (1992–1998). The system study tools adapted to the market conditions were used from 1999 to 2008 to develop the documents for strategically planning the development of the country's power industry. Theoretically, this activity was continued after the 2009 economic crisis; later, however, it lost its systemic character and did not apply advanced studies into the prospects of the developments of Russia's economy. Finally, the courses of the development and potential applications of this research area are discussed in alternative, *mobilizing* or *liberal*, concepts of the organization of the "future information society" (2035–2050). In this review, publications on the management of the *development* of large-scale energy systems are considered. The aspects of their optimal *functioning* are the subject of another review[3].

*Keywords:* power industry, fuel and energy sector, system studies, planning of the development, mathematical models, optimization

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Although it was in pursuit of propagandistic and political goals, the first-ever long-term vision of the development of the power industry in conjunction with the economy, the State Plan for Electrification of Russia (the GOELRO Plan) [1] became a revolution in the economy's management. During the 9-month long development of the Plan, the team of leading scientists and talented engineers chosen by Krzhizhanovsky [2] did not have time to deal with methodological subtleties. Nevertheless, the plan's documents demonstrate the formulations of the then-cutting-edge research problems and approaches to the substantiation and choice of effective solutions. L.A. Melent'ev noted 60 years later that, in the GOELRO Plan, the main philosophy of planning the national economy based on the concept of electrification as the driving link of the economy and the scientific understanding of the power industry as a coherent whole was founded [3].

Severe experience of the Stalinist 5-year plans, World War II, and the restoration of the national economy demonstrated huge mobilizing capabilities of the planned economy and its fuel and energy sector but did not lead to fundamental advances in the meth-

[1] For the full text of the review of 180 publications on the subject, predominantly treatises, refer to www.eriras.ru

[2] Makarov, A.A. and Mitrova, T.A., The Centenary of the GOELRO Plan: Capabilities and Problems of the Planned Economy, *Therm. Eng.*, 2020, vol. 11, p. 5–16. https://doi.org/10.1134/S0040363620110089

[3] *Sistemnye issledovaniya v energetike: retrospektiva nauchnykh napravlenii SEI–ISEM* (Systems Studies in the Power Industry: Retrospective Review of Research at the Siberian Power Engineering Institute–Melent'ev Institute of Energy Systems), Novosibirsk, Nauka, Siberian Branch, 2010. Treatises on the development of the power industry listed in the references of the book are included in this review but structured in a different way and supplemented by publications of the recent years and, most importantly, from other institutions.

odology and planning tools[4]. The preconditions for a qualitative leap in the methodology, methods, and tools for planning the development of the power industry as one of the bases of the economy matured only in the mid-1960s, namely,

1. The understanding of the power industry as a totality of processes of generation, conversion, distribution, and use by consumers of energy resources, such as fuels, hydropower, wind power, solar energy, and all kinds of energy [4], and the energy balance as a method of a comprehensive quantitative and qualitative characterization of the generation and application of fuel and all kinds of energy in the national economy on the whole and in its branches and the regions of the country [4].

2. The mathematical theory and the methods for searching for the extremum of convex functions in multidimensional space of linear constraints and their economic interpretation [5] developed by L.V. Kantorovich paved the way to the formulation and solution of complicated problems of the optimal management and planning of the economy, including the optimization of the fuel–energy balances.

3. The creation of electronic computing machines in the early 1950s and their increasingly widespread application [6] in research and development made the previously incompletable amount of computing necessary for the implementation of the first precondition, namely, computing the balances between the generation and consumption of all kinds of energy resources over the territory of the country, and, especially, the second precondition, namely, optimizing the above processes during the functioning and development of the power industry, physically possible.

The new methodological and computational base made the 1960s the "Sturm und Drang" period in the development of various economic–mathematical models and methods for optimization of solutions for the power industry and application of the latter to the problems of the development of the country's energy sector. Research in this field was conducted under the leadership of the Siberian Power Engineering Institute (SEI), Siberian Branch, USSR Academy of Sciences, founded 60 years ago. In [7, 8], a mathematical model was proposed for the optimal planning of the power industry's development, which was specified, in cooperation with other institutions, for different branches of the fuel and energy sector (FES) [9–13] and regions of the country [14].

[4] *Sistemnye issledovaniya v energetike: retrospektiva nauchnykh napravlenii SEI–ISEM* (Systems Studies in the Power Industry: Retrospective Review of Research at Siberian Power Engineering Institute–Melent'ev Institute of Energy Systems), Novosibirsk, Nauka, Siberian Branch, 2010.

## THEORY, METHODS, AND APPLICATIONS OF THE SYSTEM STUDIES INTO THE DEVELOPMENT OF THE POWER INDUSTRY IN THE SOVIET UNION[5]

According to [15], the *system study methods* are applied to investigate the objects and phenomena of the outside world that

1. Possess a property of a whole that is not reduced to the sum of the properties of their constituents.

2. Have complex internal and external links and synergy effects of the interactions between the components that create the basic factors of the growth of the systems' efficiency, viz., concentration, centralization, combination, and specialization of the basic constituents of their economic activity.

3. Comprise management objects, tools, and mechanisms, including the financial mechanisms, normally of a complicated hierarchic structure.

4. Obey the principle of least action, i.e., provide for the optimization of the decisions to be taken.

5. Have an undefined state in the future, which poses risks to the decisions taken and requires the adaptive management of their functioning and development.

The tool of system studies is the *system analysis* that ensures the improvement of the existing and the development of new means of studying the specifics of the functioning and development of the systems to ground effective decisions. It is based on mathematical descriptions and computer simulation of the evolution of the system of

1. Natural, productional, social, and economic characteristics of a system, the locations of its elements and the links between them in interaction with other systems.

2. Management conditions and mechanisms.

3. Efficiency criteria of the system under functioning and development.

*The subject* of the system studies of the power industry is the determination of the composition and interconnections of the systems designed to provide human activity with all kinds of energy and the investigation of their status and prospects in order to enhance their efficiency[6]. The commitment to the *mathematical description (modeling)* of a particular problem in all diversity of its aspects and links constitutes the basic content of system studies in general and those of the development of the power industry in particular.

[5] A rapid growth in the number of journal publications forced the author to restrict the review here and below to only accessible monographs with state registration, namely, those provided with an index code or an ISBN number.

[6] Simultaneously, system studies into the development of transportation were conducted promoting cross-fertilization of both research lines (see Livshits, V.N., *Sistemnyi analiz ekonomicheskikh protsessov na transporte* (Systems Analysis of Economic Processes in Transportation), M.: Transport, 1986.

It took several years to correctly represent the multiplicity of fuel and energy kinds and their sources; transportation routes to the consumers; the diversity of technologies and daily, weekly, and yearly modes of generation; processing; and consumption in terms of the formal linear programming problem solvable by the method of Kantorovich [5]. It was even more difficult to formalize the development of the above processes in time accompanied by reconstruction and decommissioning of the enterprises in operation and construction of new ones, which required, in turn, the description of the production processes in the allied industries. The optimal solution to this immense task had be sought at undefined values of all numerical parameters used in the model. There is no complete formulation of such a problem; therefore, until the early 1970s, problems of the optimal development of different sectors of the power industry were being multiplied in a chaotic way.

The main tasks of the theory of system studies into the development of the power industry were

1. Structuring the power economy of the country in the form of systems according to the production (branches, enterprises, etc.) and geographic (republics, economic regions, etc.) attributes.

2. Developing the methodology and the methods for coordinating the optimal development plans through the entire system hierarchy.

3. Determining the set of basic properties of the different-level systems and the intensity of their manifestation as well as the development of the methods for considering the above properties for the optimal development of the power industry.

At the 1970 All-Union symposium [16], the formation of the theory and methods of system studies into the development of the power industry began. *The large energy systems (LESs)* were interpreted as hierarchically arranged man–machine systems of a complicated structure that functioned being provided with incomplete information. Subsequently, numerous journal articles and local publications appeared that discussed theoretical problems, methods, and tools (mathematical models) for investigating the structure and properties of the LESs and solving a wide range of problems related to their development. As applied to the tasks of the optimal planning of the power industry, new scientific and methodological developments were summarized in [17] and the possibility of their use in the practice of planning and design was *first* set down in governing documents [18, 19].

In [20], L.A. Melent'ev specified the tasks of the optimal management of the development of the Soviet Union's general power system and electric-power, nuclear-power, and pipeline systems that comprise the former. The development of the Automated Planning/Accounting System (APAS) for the Soviet Union's Gosplan (State Planning Committee) [21] offered the possibility of a radical improvement in the planning of the country's economic progress with the power industry leading in the development of automated systems for intersectoral complexes.

As a result, by the mid-1970s, a sufficiently coherent and complete scientific school of thought on the systems studies in the power industry had been established in the Soviet Union. Its theoretical and methodological sections are comprised of [22]

1. Studying the nature of the energy systems, the composition and intensity of manifestation of objective trends in their development, and the investigation of the structure, external and internal links, and properties, such as stochasticity, dynamics, and manageability and their specific manifestations;

2. Improving the methods for studying the energy systems, including the construction of their adequate mathematical models, the development of methods for optimizing the dynamics under lack of complete information on the conditions and aims of the development of these systems, and construction of more perfect decision-making models and procedures.

3. Improving the informational support for the energy systems, including the facilities for data acquisition, processing, and transmission, as well as the verification and use of the information.

The above scientific and methodological aspects of the system studies of the power industry were developed in treatises on the methods and models for coordinating decisions in the hierarchy of the sectoral and territorial energy systems [23] and making the optimal decisions on the development of the LESs under uncertainty of the input information and decision optimization criteria [24].

Practical results from exploring the status and prospects of the fuel and energy sector and electric power engineering of the Soviet Union for 10–15 years and the specific features of the fuel supply of the country's regions are presented in [25]. In this work, the sustainability of the trailing fuel expenditures by the regions of the country are analyzed and their recommended values as a tool of coordination of the results of various engineering and economic analyses in the power industry with the optimal development of the fuel and energy sector of the country are determined.

The results were supplemented by the systems approach to the management of the development of the electric power engineering and heat supply, the nuclear power system and gas supply, and the interconnections between the development of the power industry and the economy. The preparation for the use of the methods for the system analysis of the development of the power industry was supported by the development of the first stage of the "Fuel and Energy Sector" subsystem of the Automated Planning/Accounting System of the Soviet Union's Gosplan [26].

The active participation of Soviet specialists in the energy project of the International Institute of the Applied Systems Analysis (IASA) established in 1972

resulted in the leading position of the Soviet Union in the development of the theory and methods of system studies into the development of the power industry [27].

The methods and models for system studies into the development of the power industry had their "baptism of fire" when the Soviet Union's Long-Term Energy Program was developed in 1979–1980 [28]. Various scenarios of the optimal development of the energy sector and its industries for the period up to 2000 were computed in the Soviet Union's Gosplan computing center and analyzed for their influence on the development of the country's economy. The results of the studies were presented in outline in [29] and included into the assignments of the next 5-year plan for the development of the Soviet Union's national economy. From the point of view of the methodology, they were considered in the second edition of a treatise on the system studies in the power industry [30], set down in the methodological recommendations for the determination and use of reduced and trailing fuel and energy expenditures [31] and for the study of the technical and economic feasibility of design solutions in power engineering under ambiguity of the input information [32]. The experience acquired was summarized in treatises published at the Siberian Power Engineering Institute and the Energy Research Institute on theoretical fundamentals of system studies in the power industry [33], the methods for the investigation and management of energy systems [34], and the solution of complex problems of the development of the country's power industry [35].

However, starting from the mid-1980s, the Soviet Union was losing its leading position in the development of the methods and tools, especially, in the performance of the computing machines, for system studies of power engineering. The United States created the MARKAL national energy model and the International Energy Agency was regularly using these and more high-powered systems analysis tools for prediction of trends in the development of the global and regional power industries.

In the late 1980s, using system analysis methods, the Soviet Union's Complex Program of Scientific and Technological Progress (Section "Fuel and Energy Sector") was developed in which the targeted greenhouse gas emissions caused by the power industry were minimized and the survivability of large energy systems under conditions of a large-scale war was investigated [36]. However, the progressive slowdown in the development of the economy and changes in the foreign policy shown in the article on the GOELRO Plan[2] had made the basic provisions and forecasts of the Soviet Union's Energy Program invalid by the late 1980s [28, 29].

To sum up, we should note that the results of using the methods of system studies into the development of the power industry in the Soviet Union cause a rather ambivalent attitude. Theoretically, they are immanent in the system of centralized planning and were successfully used when preparing long-term programs of the energy and scientific-technological development. However, during development of the most significant 1-year and 5-year plans of the development of the power industry in the Gosplan, the tools of the automated planning/accounting system were used only to perform the substantiating alternative calculations. Great hopes pinned in the 1970s on the capabilities of system study methods to radically accelerate the development of the economy did not come true either. The economic discipline impaired in the 1980s after the market reform initiated by A.N. Kosygin and increased corruption of the accounting information by enterprises devalued the use of the formalized methods for planning the development of the power industry.

## METHODS AND APPLICATIONS OF SYSTEM STUDIES INTO THE DEVELOPMENT OF THE POWER INDUSTRY IN RUSSIA

The collapse of the Soviet Union and the transition of Russia to the "market" destroyed the system and bodies of the planned economy. As far back as in 1992, the Academy of Sciences jointly with the Ministry of Energy actively developed the Concept of the Energy Policy of Russia under New Economic Conditions adopted by the government [37]. Since that time, the adaptation of the methods and tools of system studies into the development of the power industry to the market relations began.

The studies provided a firm scientific basis for the development of the Energy Strategy of the Russian Federation for the Period up to 2010 (ES-2010) [38] in which the role of the fuel and energy sector in the medium-term program of the development of the Russian economy, in the integration of the CIS countries, and the formation of the Eurasian Energy Space, as well as in the assurance of the energy security of Russia, was determined.

The increased role of the fuel and energy sector in the national economy and the tasks of its reformation necessitated updating the strategic documents. In the Energy Strategy of the Russian Federation for the Period up to 2020 (ES-2020) [39], alongside the development of the fuel and energy sector in the market economy conditions, the accent was on energy efficiency and security, regional energy policy, and ecology[7].

The transition to the market relations necessitated adapting and extending the capabilities of the Soviet methods of system studies into the development of the power industry, whereas the advances in computing

[7] The monitoring of the implementation of the ES-2010 and ES-2020 showed that the development scenarios of and forecasts for the FES and its industries appeared to have been executed to 82 and 80%, respectively [40, Tables 1.2 and 1.3, pp. 19–21]. Unfortunately, the forecasts of the subsequent strategic documents were and are being implemented to a far lesser extent.

technologies, especially the accessibility of more powerful networked personal computers, allowed the mathematical models to be increased and complicated by several orders of magnitude. Cumbersome *optimization* models were framed and built-up with *simulation* models developed by specialists to work within their subject fields. The multiple particular models were integrated into a unified tool of the system studies into the development of the power industry using *distributed databases*.

The Energy Strategy of the Russian Federation for the Period up to 2020 was developed using a conceptually new computer-simulation system StraTEK (Strategy for the FES) [41]. The destruction of the centralized planning system led to the disappearance of the sources of information on the development of the economy necessary for power engineering specialists and there were no retrospective data available in the country sufficient for a correct use of statistical prediction methods. Therefore, system study tools had to be supplemented by a full-fledged system of *economy development models*.

New economic conditions necessitated substantial extension of mathematical models in the development of the FES branches. They had previously been aimed at optimizing the development and utilization of the *production capacities* and *ties*; under new conditions, it became necessary to optimize the *financial flows* and *organizational structures* of the FES and large-scale companies as well. This forced researchers to switch from multidimensional linear programming problems to nonlinear problems of much larger dimensionality to explore the variants of the formation of energy markets and the reformation of natural monopolies, primarily of electric power generation and the gas industry.

An important task of the structural policy of the ES-2020 was the improvement of the organizational structure of the FES and the formation of a competitive environment in the gas industry and electric power generation. These recommendations, however, were implemented to a far lesser extent than the forecasts for the development of the FES industries.

The 2008 global financial crisis decreased the gross domestic product (GDP) by almost 8% and the production of energy resource by 5% putting an end to the "golden decade" in the development of the Russian economy and power industry. After the leadership of the country had changed, the previous objectives to accelerate the economic growth were replaced by a paradigm of sustainable development. The planning of the development of the power industry was conducted merely as a formality; the trend towards the market transformation of the industry was replaced by a trend towards the strengthening of state capitalism. Automatically, the Energy Strategy of the Russian Federation for the Period up to 2030 was adopted [42]; however, the scenarios of the economic development set forth in this document proved to be too optimistic, which made the forecasts for the domestic demand for fuel and energy unrealistic and distorted the vision of the FES's development pattern.

The reduced needs of the authorities and the global economic crisis heightened the interest in methodological investigations, prediction of the interconnections between the power industry and the economy [43], and the trends in the development of the global power industry [44].

The Energy Research Institute has accomplished the formation of the SCANER[8] simulation–information complex [45]. It supplemented the StraTEK complex [41] by a system of models of the development of the global power industry and energy markets and was regularly used to provide forecasts for the coordinated development of the global and Russian power industries until 2035–2040 [46]. Special attention was paid to the dynamics of the European and Asian fuel markets that are of particular significance for the country.

In 2014, after years of discussions, the law on the strategic planning in Russia, which regulates the composition and content of the planning process in the country, was adopted [47]. The generally satisfactory implementation of the content and terms of the development of high-level strategic documents specified in the law is in contrast to the hampered implementation of the regulations on the planning of the economy and its industries, especially the power industry. The correction of the Energy Strategy of the Russian Federation for the Period up to 2030 prolonged to 2035 (ES-2035) commenced in 2013 was not supported by updated forecasts for the social and economic development of the country. The need of the state for the studies aimed at improving the energy markets and energy security of the country were reduced. As a consequence, scientific research was switched to the generalization of the results on the methods and models of the development of the power industry obtained over decades [48] and making well-founded long-term forecasts for the development of the FES [49].

A breakthrough was achieved in the description of the development of production–economic systems as a set of agent-based models[9] and their use in the configuration of the SCANER complex for the medium-term and long-term prediction of the development of the power industry in interaction with other industries [50]. The latest achievements in the methodology and applications of system studies to the development and functioning of the Russian power industry are summarized in [40]. The methods and "price" of the adaptation of the power industry to the postcrisis development of the economy were investigated, the fundamentals of the economy and management of the

[8] Super Complex for Active Navigation in Energy Research.

[9] In these models, the development of a system is described as an interaction of autonomous agents (subsystems) with each other and the outside world with their conditions (restrictions) of and priorities in the decision making.

modern electric power production of Russia were described, and the influence of the technological advances on the development of the global power industry and the intensification of the switch from fossil fuels to carbon-free energy sources was studied. The threats to the development of the power industry—the reduction in the fuel export—and economy of Russia caused by the latter circumstances and the measures to be taken to mitigate the adverse consequences are investigated in [51].

These results, however, were not deemed necessary to be considered in the latest version of the Energy Strategy of the Russian Federation for the Period up to 2035[10].

## INSTEAD OF CONCLUSIONS: WHAT NEXT?

System studies into the development of the power industry are exciting; their results, however, are being applied in the country spontaneously and to a lesser degree yet. This fact is evidenced by Table 1, in which 16 lines that comprise the basic *scope of work* on the planning of the development of the economy and power industry are grouped according to three *aspects*, viz., planning stages and tools, sources of the necessary information, and the composition of the planning results.

As mentioned above, under socialism, the application of system methods in the power industry ended in the development in the Soviet Union's Gosplan of proposals for long-term plans and optimization calculations for 5-year plans (see Table 1, column 1).

Under state capitalism, the application of system study tools (mathematical models) to the planning of the development of Russia's power industry was extended to the development—every 5 years or so—of the Energy Strategy of the country, master plans, and programs of the long-term development of the FES industries and included the formulation of the corporate strategies of the companies with state participation. Presently, the planning at all levels is performed using computers, e-mail, and the Internet; the decisions on plans are taken by large-scale companies based on the internal market forecasts (see Table 1, column 2).

According to the law [47], the strategic planning of the economy and power industry of Russia was changed from the *normative* planning used in the Soviet Union, which means a detailed plan for every enterprise, to the *indicative* planning of the development objectives and the tasks and tools for their achievement at a limited number of quantitative indices of the successful implementation of the plan. It was in this way that the forecasting activity was arranged in the United States in the 1990s. At the beginning of the 21st century, China switched to the concept of short-term strategic planning of the economy, including the power industry[11]. In addition to the above-mentioned irregularity of the process, the implementation of the indicative planning of the economy and power industry is hampered in Russia by the involvement and badly founded documents under development. Indeed, in the United States, and in China to a lesser degree, the entire hierarchy of indicative planning is supported by publicly discussed model forecasts developed on a competitive basis by powerful, well-funded research institutions. In Russia, however, the feasibility study of the strategies and the programs of the development of the economy and power industry is fragmented predominantly between academic organizations weakened by the reform, and the documents are discussed selectively and pro forma and, for the most part, neglected in the planning documents.

The development of the concepts and programs of "digitization" of Russia's industries and companies for the period until 2024 commenced in recent years are still oriented towards the acquisition and identification of the accessible information used exclusively for the purposes of the *operational* management of enterprises or industries[12]. But the fourth (digital) violently ongoing industrial revolution will not offer any alternative to the widespread use of the system study methods and tools to manage the *development* of the economy in general and the power industry in particular.

Below, without discussing the social aspects of the information society[13], we outline *alternative concepts* of the use in the following 15–25 years of the system methods and tools to plan the development of the power industry as a part of the national economy.

In an unfavorable geopolitical situation, in some countries, including Russia, *mobilization* digital economy may be formed when the centralized planning reaches the level of households (See Table 1, column 3). Within the framework of this concept, the plans for the development of the economy (and the power industry) are calculated in the ***computer networks*** using a ***megasystem*** of industrial–territorial ***mathematical models***[14]. The input information for the latter will be formed via ***neural networks*** using ***report databases*** and their uncertainty estimates. According to the results of the optimization calculations, other neural networks will generate representative ***system development scenarios*** and form a corresponding prescriptively established ***indicative figure matrix***.

[10] https://minenergo.gov.ru/node/1920

[11] *Aktualnyi opyt zarubezhnykh stran po razvitiyu gosudarstvennykh sistem strategicheskogo planirovaniya* (Relevant Experience of Foreign Countries in Developing National Strategic Planning Systems), M.: NIU VShE, 2016.

[12] Refer to: http://www.tadviser.ru/index.php/: Information Technologies in the Federal Revenue Service.

[13] Rheingold, H., Smart Mobs: A New Social Revolution, M.: Fair-Press, 2006.

[14] Although the successful development of artificial intelligence will make the use of mathematical models unnecessary.

**Table 1.** Aspects and stages of the evolution of system studies into the development of the power industry*

| Aspects and scope of work | | Evolution stages of system studies | | | |
|---|---|---|---|---|---|
| | | Planned economy (Soviet Union, 1980–1991) | State capitalism (Russia, 2000–2020) | Information society (2035–2050) | |
| | | | | mobilization | liberal |
| Stages and tools of planning | Plan development depth | Up to the enterprises | Country, ministry | Planning up to the households | No plan |
| | Use of mathematical models | **State Planning Committee**, ministries | **From the country to the enterprises** | **System of power industry development models and/or artificial intelligence** | **Agent-based models of the power industry and economy agents** |
| | Use of computing machines | – | Same | | |
| | Communication means in use | Mail, telephone | Mail, telephone + **Internet** | **Superinternet** | **Superinternet** |
| | Coordination of decision-making in the power industry | Country, ministry, enterprises | Country, ministry | **From the country level to the households** | **Simulation of the operation of the markets under lack of information** |
| | Consideration of the interactions between the power industry and the economy | Ministry (in detail) | Ministry (in outline) | Integration of the power industry into the economy | |
| | Adoption of plan decisions | Ministry. Below, plan targets | **Country, enterprises** | Upper management level | **Decentralized** |
| Information sources | From allied industries | To a lesser degree | To a lesser degree | **Integral databases on power industry, allied industries, and consumers** | **Formed when simulating the operation of the market** |
| | In outline from the upper level | Ministry | Ministry + state-owned companies | | |
| | Internal forecasts | To a lesser degree | **Most enterprises** | | |
| Results of planning | Directive plan | In general | – | **Optimized plans of the development of the enterprises and power consumption regulation** | **Market participants take their plan decisions and accept development risks** |
| | Taxes | State | State | | |
| | Prices | ″ | State (partially) | | |
| | Investment projects of enterprises | Ministry | Ministry for state-owned companies | | |
| | Rules of economic management | State | State | State | Economic Counsel |
| | Planning improvement | ″ | ″ | ″ | Same |

* In bold type, the aspects of the planning activity are highlighted that apply system study tools.

Based on the above, the responsible authorities take decisions that are automatically transformed into detailed production and investment plans, prices and taxes for the enterprises, and rates of consumption for people[15].

The alternative *liberal* economy concept agrees with the optimistic professional vision[16] of the trends in the development and application of information technologies (see Table 1, column 4). Such an approach supposes the *absence* of even an indicative plan and the ***self-organization*** of all market participants in the complicated process of predicting the future. The input information is formed via neural networks and according to it multiple economy evolution scenarios are developed in the ***computer networks*** using a set of ***agent-based models*** of the market participants. Based on these scenarios, the market moderator (the Economic Counsel) forms, according to the set of criteria of the volume and growth quality maximum with the systems risk minimum, a preferable economy development *corridor*, including the development of the power industry. Every participant,

[15]The idea of the economy "digitization" concept developed in the Soviet Union is set forth in terms of the current information technologies: Glushkov, V.M., *Makroekonomicheskie modeli i printsipy postroeniya OGAS* (Macroeconomic Models and Principles of Construction of the National Automated System), M.: Statistika, 1975.

[16]K. Kelly, "The Inevitable: Understanding the 12 Technological Forces that will Shape Our Future," NY: Viking Press, 2016.

being a *decentralized autonomous organization* (DAO), using ***blockchain technologies***[17], can control all information processes and determine their ***potential opportunities and risks***. The collegial market bodies make amendments to the rules of the market operation and improve the requirements for the tools.

Consequently, when implementing the liberal digital economy, the traditional research methods should be supplemented by the use of

1. Neural networks, image recognition techniques, and other artificial intelligence tools.

2. Agent-based models and methods of their interaction.

3. Distributed ledger (blockchain) technologies.

However, it is still unclear when and to what degree this concept will be implemented, but the mastering of the above-listed means and technologies will significantly advance the methodology of system studies into the development of the power industry.

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