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THE SYSTEM FOR ORGANIZATIONAL MANAGEMENT OF THE IMPLEMENTATION OF THE PROGRAM FOR THE DEVELOPMENT OF EXAFLOPS TECHNOLOGIES

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Economical and organizational assessment and recommendations on the transition to new adaptive-network type of organization of production, financial flows and exchange relations, meeting the requirements for the implementation and functioning of exaflops technologies

Keywords: *Gigaflops, Teraflops, Petaflops, Exaflops, Very-large-scale integration circuits, Network planning and management.*

The information era in the development of productive forces of developed countries is nearing a qualitatively new starting-point – that of technologies of high-performance computing on the basis of super computers of exaflops class (10^{18} arithmetical operations with real numbers per second).

The first supercomputers had capacity of approximately 1 kiloflops, that is 1 000 operations with a floating point per second. The CDC 6600 computer with 1 million flops (1 megaflops) was developed in 1964. The level of 1 billion flops (1 gigaflops) was exceeded by the Cray-2 supercomputer in 1985 with a wide margin (1.9 gigaflops). The level of 1 trillion flops (1 teraflops) was reached in 1996 by the ASCI Red supercomputer [1]. Currently the works to develop exaflops computers able to perform 1 quintillion operations with a floating point per second, by 2016, are underway.

This process is vividly illustrated by the Diagram reflecting the correspondence of an object being researched at atomic level and capacity required for such research (fig. 1) [2].

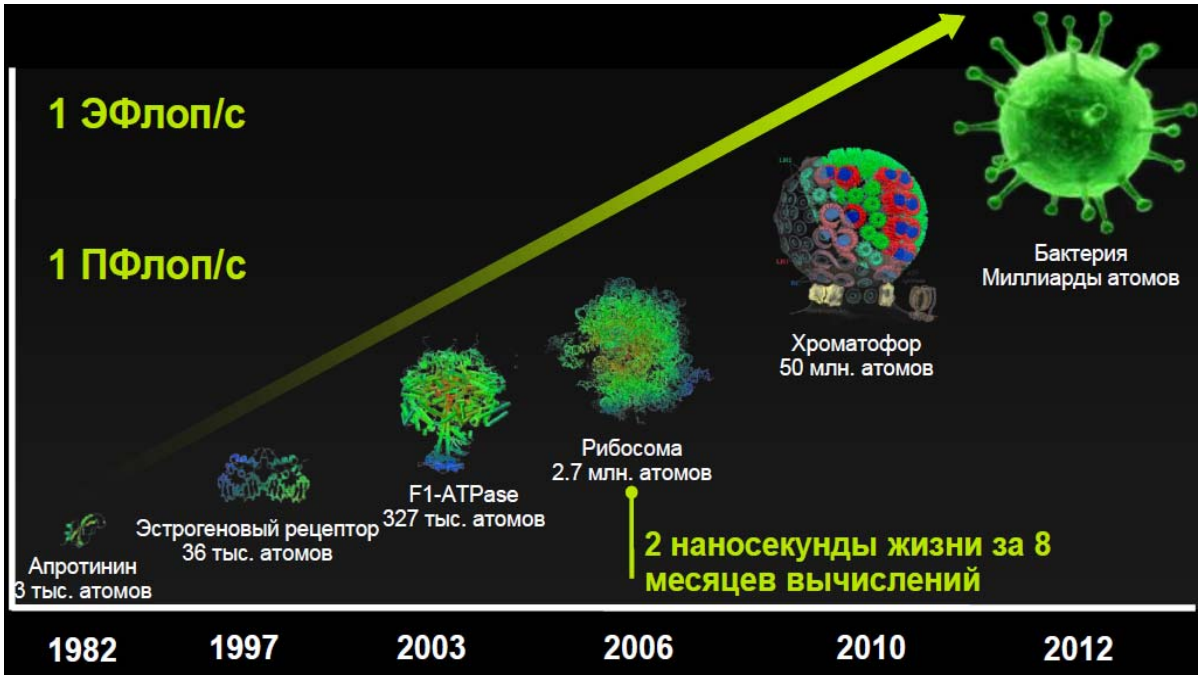

Fig. 1. Correspondence of an object being researched at atomic level and capacity required for such research

Table 1. The countries expenditures for the development of petaflop and exaflop-scale supercomputers

Floating-point Operations Per Second	USA	European Union	China
1 pflops	DOE – over 100 mln.$/year; NSF and universities – up to 30 mln.$/year; DARPA UHPC – about 75 mln.$ for 4 years; in total nearly 150 mln $/year without hardware cost will be spent on research	The European Commission, PRACE, DEISA and EESI programs, national programs, universities and industry. In total 29-43 mln.$ per year for research without hardware cost.	2012 – petaflops-scale supercomputer on own hardware components Open part of financing – 67 mln.$
10 pflops	2011-2012. 20 pflops: Sequoia, Titan 10 pflops: Mira	2012-2013. SuperMUC – 3 pflops Hermit – 4-5 pflops	2015 - 10 pflops supercomputer; Budget: 107 mln.$
100 pflops	2015-2016. several supercomputers (from 50 to 150 pflops)	No official data	2015-2020. several supercomputers with petaflops capacity, At least one with 50-100 petaflops capacity. Budget: 615 mln.$
1000 pflops - 1 exaflops	2018-2019 – several supercomputers (from 1 to 2 exaflops)	2020 – European 1 exaflops	2020. 1~10 exaflops Budget: information is not yet available
International Exascale Software Project (IESP) (USA, European Union, Japan, China, Russia and other countries)			

Table 2. Expert estimation of capacity of computer systems required for the development of high technology products

Applications	2011	2015	2018
Technology-intensive industries: - aircraft and shippind industries - automobile industry - aerospace industry	 0.3 pflops 0.1 pflops 0.1 pflops	 3 pflops 1 pflops 2 pflops	 1 pflops 0.5 pflops 1 pflops
Nuclear power industry	1 pflops	100 pflops	10-20 exaflops
Oil and gas industries	1 pflops	100 pflops	1-10 exaflops
New materials on the basis of nanotechnologies	1 pflops	100 pflops	1-10 exaflops
Biotechnologies	1 pflops	10 pflops	1-2 exaflops

Nowadays, the world leading states are making considerable efforts to develop exaflops technologies (Table 1) [3], able to solve the problems of the development and production of high technology products (Table 2) [4].

Exaflops calculations can produce double effect:

- on the first hand, the effect of exact knowledge of complicated internal – endogenous properties of investigated or designed subject area and technologies (military, aerospace, chemical, biochemical, biological) and of their consumption value for humans;

- on the second hand, the effect of exact knowledge of external, no less complicated exogenous links and interdependences (inter-industry) of each investigated, designed and programmed subject area and technologies. Such knowledge would help in the selection of such organizational structure and management system, which to the maximum extent meets the challenge of an effective and fast implementation of an innovation project.

Industry-specific (endogenous) exaflops technologies

Typically the substantiation of the necessity of exaflops calculation capacity is proved at the level of industry-specific technologies developed and organized mainly with the use of one's own resources. And such substantiation is quite justified, as it is evident to researchers and experts that further progress in machine-building industry, material engineering, nuclear and conventional thermal power generation, medicine and pharmacology is not feasible without computer simulation at the level of atomic-molecular interactions, which require computational resources of the order of 1-10 exaflops [5].

Atomic-molecular level of computer simulation and computational resources makes it possible to solve the most complicated problems of integration of large-scale complex processes with specified accuracy in intrinsic time[1] of each process, with the use of optimal quantization and most effective algorithms to ensure effective data exchange [6].

Exaflops computation technologies can bring a revolutionary breakthrough in effective implementation of advanced prospective target programs and projects: aerospace [7], aviation [8], nuclear [9], military [10], medical [11] and scientific research ones [12].

Let us consider endogenous industry-specific peculiarities of the coming exaflops stage in three areas – computer technologies, fuel power industry and finance:

- Strategic computer technologies and software [13]. Operating environment for a computing system with capacity of 0.01 exaflops; 0.1 exaflops; 1 exaflops (1 exaflops = 1000 petaflops; exa – 10^{18}). The development of effective topology-oriented communication interfaces and libraries for computing systems with capacity of 0.01 exaflops; 0.1 exaflops; 1 exaflops. The system for hierarchical data storage including parallel file system with capacity of 0.01 exaflops; 0.1 exaflops; 1 exaflops. The development of software to ensure fault-tolerance of a computing system. The development of scalable programming software providing parallelization and simultaneous execution of ~10^8 processes. The setting-up of an integrated system for job control and resources management, providing optimal allocation of processes in computing elements and reliability. The system for automated engineering of multiprocessing environment. Software tools for cross-platform calculations and cloud computing. The development of VLSI (very large-scale integration circuit). microprocessors and communication VLSI on the basis of silicon in accordance with 45 μ design rules. The production of VLSI with design rules at least 45 μ at the Russian Federation territory. The fabrication of dedicated supercomputer with 100 petaflops capacity on the basis of domestic hardware components. The modernization of the developed VLSI on the basis of the 2016-2017 technological process. The development of the 500 petaflops supercomputer on the basis of domestic hardware components. Then, the development of the 1 exaflops system with the use of domestic hardware components. The development of federal supercomputer centers on the basis of the existing computation centers: the Computer Center of the Russian Federal Nuclear Center - All-Russia Scientific Research Institute, the Computer Center of the Moscow State University named after M.V. Lomonosov, the International Computer Center of the Russian Academy of Sciences, the Computer Center of the Research Center "Kurchatov Institute". The setting-up and development of regional and industry-specific supercomputer centers in large RF regions with considerable science-intensive potential, as well as at large-scale higher educational institutions, leading enterprises of high-technology industries and industry research institutes. The association of industry and federal centers integrated with a unified open (with the exception of secret areas) state information system, thus providing the formation of the matrix of productive and intellectual resources.

- New types of fuel [14]. For example, the technology of Cold Nuclear Transmutation CNT). On October 8, 2011 Andrea Rossi made a successful presentation of the large unit 8 E-cat (37 modules, 3 cells each) with output heat capacity of ~ 1 MW. This fact demonstrates that in the nearest future Cold Nuclear Transmutation will be rapidly developing in both theoretical and experimental terms. In this connection, it should be mentioned that in this country it is **vital to use preferential taxation of investment into scientific research** for further development of breakthrough technologies able to radically change the situation.

So far Yu. N. Bazhutov (fig. 3) has obtained the following results in the field of Cold Nuclear Transmutation [15]: 1) maximal neutron yield in the world – up to 500 000 per one session; 2) thermal yield 500%.

These results by far exceeds those by A. Rossi. In the scientist's words, it is possible to

[1] Scalar variable with values on the number axis, used for calculating process states.

fabricate a fully operational power plant in 3 years and in 5 years the plant capacity can be increased up to 30 MW, which can provide energy supply to an exaflops computer center. Commercialization of the Cold Nuclear Transmutation technology will allow **to minimize oil and gas dependence without loosing revenues [16]!** It is extremely urgent not loose time and specialists with unique knowledge and experience. If we miss a chance today, tomorrow other countries will be selling us these technologies, at the same time reducing purchases of our oil and gas. The scientist mentions that "Rosneft" is aware of the Cold Nuclear Transmutation but so far no steps have been made.

Fig. 2. A. Rossi and S. Focardi E-cat Stand [14]

Fig. 3. Yu. N. Bazhutov

- **Financial.** The development of advanced econometric models with risk calculation for non-linear instruments and organization of risk-oriented bank supervision, the solution of part of problem within the framework of the future financial center, etc.

In this connection it should be mentioned that in the current situation of low and moderating rate of economic growth not only preferential taxation of investments into scientific research for the development of breakthrough technologies able to radically change the situation, but also grunt funding and low-interest financing are of vital urgency.

Without any double, financial sector and its part – the theory of high-risk investment (both due the very nature of this sector and theory, as well as of its corruption component) should be radically modernized in the line of the setting-up of risk-oriented bank surveillance. Leading Russian banks are supporting the idea of such surveillance, considering the analysis carried out by Russian [17] and foreign [18], as well as by the Bank of Russia [19].

Information-computer essence of risk-oriented bank surveillance is that in simulating economic systems it is necessary to solve the problem of considering non-linear risks in real time mode using the Monte Carlo method. This method accuracy is by far higher in comparison with the others. High performance computing on the basis of exaflops supercomputers will make the following systems universally available in real time mode:

1) Systems of early warning of emergencies both for an individual bank and the whole financial system;

2) Advanced econometric models with risks calculation for non-linear instruments (the use of any distributions and simulation of market complex behavior; trends; clusters of various volatility; changing correlations among risk factors; "what if" scenarios; practically unlimited models development).

Active and effective work of the Bank of Russia, the new MEGA-regulator in combination with the development of other segments of economic organization and management, notably, effective bi-level system of management of economy (considered below); the technology of calculation on the basis of exaflops supercomputers; the implementation of advanced economic models and risk-oriented bank surveillance providing knowledge for well-founded strategic and operative decision-making that may prevent critical situation in financial field, etc. – all these will be a set of measures for adequate and effective prevention of crisis phenomena.

Here it is probably appropriate to answer a question concerning rationality of implementation of the Basel Committee recommendation – Basel 3.

For an adequate answer to the question raised we should consider the fact that it were mainly ex-

perts from the USA who initiated and developed the Basel 3 recommendations and their concept of economy was principally based on the US interests and the experience of the use of the Dodd Frank Act in the USA as applied to the US economic reality (the Act was adopted after the 2007–2008 crisis). However, this mere fact is enough to make a conclusion on the necessity of a most thorough analysis and evaluation of the whole set of recommendations and selection of only those of them which can benefit Russia.

Russia's economy considerably differs from the US economy both in terms of the level of development and the range of both problems and the methods of their solution. Therefore, the implementation of the Basel 3 provisions on a full scale can easily become a costly imitation of economical and management activity, because, according to expert opinion, it will increase the funding costs, reduce crediting and, consequently, slow down the rate of the country economic growth in general.

However, it is quite evident that Basel3 contains a whole range of exceedingly useful for Russia requirements, notably, the requirement to provide transparency of financial flows and to tighten government control of financial flows and operations on this information base of government control.

The Adaptive-Network Type of Organization of Production, Financial Flows and Exchange Relations

In their leading-edge computing capacity the above-mentioned examples (the list is not by far complete) of information-intensive and cost-intensive industry technologies, as well as technologies of high-performance computing on the basis of exascale super computers, are not only endogenous – industry-specific technologies but mainly exogenous inter-industry technologies (to be more precise, network technologies wherein activity graph is represented by the "tree" type).

These technologies are establishing a brand new economic and organizational era in the development of society – the era of network inter-industry organizations easily adaptive to effective and fast implementation of research and technology projects able to provide rapid growth of Russian economy and the high quality of its development.

Economic and organizational roots of this era emerged in the USA in the course of the implementation of the military project for the development of the sea-based missile known as SLBM "Polaris" (1956–1960). This project was characterized by the use of the "Pert" system and was implemented within the framework of the consortium – an interdisciplinary association of corporations headed by the Lockheed corporation. The consortium incorporated over 100 corporations, as is reported by S.P. Nikanorov, who was the first to translate the PERT system into Russian.

For the first time in economic history an inter-industry form of the organization of planned-network type, adaptive to the requirements of a complex innovation project – namely, to the requirements of planning and management of complicated network of activities carried out by enterprises of various industries (nearly 70 thousands of works were involved). It should be noted that consortiums as non-network organizational form of capital emerged much earlier – in the early 19th century.

After the 1959–1961 world crisis organizational and management mainstream was fast transformation of previously dominating trusts into concerns and consortiums (corporations) – into inter-industry organizations of capital, progressively introducing a network approach to planning and management of innovation projects and production into managerial culture.

It is evident that in this process a key role was played by state financing the space program "Space Shuttle", wherein planning and work control involved approximately a million of works carried out by many corporations.

Such capital transformation entailed a whole range of critical advantages to concerns and consortiums of network management type over trusts. Financing of target programs for end products production became by far more stable and immune to considerable corrections, as market price for intermediate products (raw material, semi-finished product, component parts) being parts of target end product, was replaced by firm transfer price planned and controlled from a control center – a parent company. Financing of target programs and financial control became inter-industry through the whole network of producers of intermediate products, thus making all the participants oriented and interested in high-quality production of end target product and saved end producers from financial and technical willfulness of trusts, that could ruin the project. Network control of intermediate products quality became possible, which is essential to provide reliability of operation of a sophisticated product and, consequently, its market value (it is known that the more complex a product is, the higher the probability of its failure in service).

In trust organization of production, network quality control of producers of intermediate products and rapid elimination of bottlenecks located beyond direct producer of products and services, are principally impossible because of impassable boundaries – barriers of commercial confidentiality of private property, contradiction between the trusts interests and the objectives of target project and of high-quality production of end product, as well as organizational and financial isolation.

The carrier rocket "Proton" failure is a vivid example thereof.

Since the emergence of laser data carriers (compact discs) emerged in 1979, the Americans already had the whole matrix of available information on 16 million items of specific products produced by the US corporations (these discs were privately demonstrated at one of the USSR enterprises). The availability of such open and universal data base on products and their producers were evidence of most favorable conditions for the development and implementation of projects and business plans for any economic participants of production of any property types – state, large-scale corporations-concerns currently dominating in the form of adaptive-network organizations, medium and small-scale private companies.

Unfortunately, in organizational and management terms we are now at the level of industry trusts whose era came to an end 50 years ago.

Our existing "concerns" are in fact merely an imitation of concerns, being in reality trusts – industry-specific enterprises whose ideal is being a self-managed center reproducing primitive contractual commercial relationships with outside direct suppliers and consumers.

Currently the most eloquent manifestation of such "outstanding" properties of this primitive industry-specific system is the organizational form for purchase of products through the "integrated official web-site of the Russian Federation in the Internet" which, as a rule, guarantees 30-50 days (!!!) of waiting for conclusion of contracts for ordered products (from the moment of order placement at the web-site).

There is a paradox in the fact that the information system, designed in its inner nature to search for the ways of reduction of time of ordered products movement from producers to consumers, is being used for quite the opposite aim – increasing their delivery period.

It is quite evident that with the use of such information system integrated into lengthy bureaucratic procedures (placing of customers proposals on the web-site, collection of competitors requests, evaluation of requests and determination of contractors to be awarded the contracts, the conclusion of delivery contracts) and ensuring their existence, innovation development and higher rates of the country economic growth are out of the question.

It is unlikely that the replacement of this system by a similar Federal Communications Commission Law adopted in the first reading on 20.06.2012, will be able to considerably reduce the time of ordering products and services, as procedures and their time parameters remain the same as in the 2005 purchasing system.

In order to overcome organizational and management lagging from developed countries and provide high and steady economic growth rate, it is necessary to adequately meet the information challenge.

In the context of the advent of the technology of high-performance computing on the basis of supercomputers of exaflops class or nearly similar in capacity, it is urgent to set up the system for organization and management of production, able to integrate technologies of high-performance computing in order to radically reduce the time of decision-making to ensure timely and intelligent managerial decisions for effective development and rapid growth of economy.

In current conditions, such a system of organization and management of production can be a two-level organizational management system. In this system the first horizontal level comprises inter-industry network organizations adaptive to the implementation of target programs and projects. The second – vertical level includes government institutions for forecasting, planning, regulation, monitoring, financing and organizational management of processes for setting-up and effective performance of inter-industry network organizations and their balanced integration into the general reproduction process providing the development of acceleration of the growth of the country economy.

In general, the second level provides favorable conditions for the development of the first level within the framework of reproduction process.

Let us consider conceptual features of the suggested system of organizational management in more detail.

The First Level of the New System of Organizational Management – Adaptive Inter-Industry Network Organizations

To set up inter-industry network organizations adapted to effective implementation of complex innovation projects, it is necessary to develop the following basic subsystems:

- a common state-scale data base on enterprises and products and services they offer, universally available, updatable and adapted to network implementation;
- a search subsystem for intermediate products (services), alongside with alternative solutions, detection of bottlenecks and decision-making for their elimination;
- a subsystem for multi-criteria selection and network optimization in terms of quality, time and cost;
- a subsystem for transfer pricing control;
- a subsystem for work evaluation and control in terms of quality, time and cost.

The Country Integrated Universally Available Data Base

First and foremost, it is necessary to develop country-scale integrated database that is universally available and regularly updated – information field whereon inter-industry network organizations adapted for the implementation of target programs, could be effectively built.

Such database should be universally available (with the exception of secret information – individual databases with various security levels) and include information on inventions and discoveries, materials being produced, commodities, services, enterprises and labor resources (both Russian and foreign). In quantitative terns, this database can include hundreds of thousands of enterprises, organizations and individual producers, as well as 10-20 million items of products and services of various types and varieties.

Such database should be developed on the basis of single standards (certificates of enterprises, organizations and individual producers, descriptions of ideas, inventions, products and services, including qualitative and quantitative characteristics, both technical and qualification characteristics and cost performance – cost-based and price characteristics adapted to network connectivity in terms of resources input and output.

Information transparency and availability to all potential users would provide the possibility of control of material and financial flows and their effectivization, notably, due to the possibilities of elimination of flows of corruptive character.

It is absolutely evident that it is only the state that can create such a basis, as a country-scale common database built on universal rules and standards, requires a centralized approach and implementation that could overcome producers intent to observe commercial confidentiality. This launch pad could and should as soon as possible be created with the use of already existing computing technologies powerful enough to become effective information tools of integration of industry technologies into adaptive network organizations (concerns and state concerns adaptive to the realization of complex target programs).

The Subsystem for Search, Selection and Transfer Pricing

The integrated universally available database would allow to make steps for the realization of subsystems for search, multi-criteria selection and transfer pricing. These subsystems should be mainly centralized tools of forming inter-industry network organizational structure of contractors and optimal network plan of their works (events) in terms of time, cost (network financial plan) and the quality of produced intermediate products.

The offered inter-industry network organizational structure for effective implementation of target programs can be legalized in the form of concerns and consortiums. Legal and physical entities of any property forms, including state, can be the system participants.

The centralization of organizational management functions at an end producer (a parent company, a holding or a special governmental organization) is determined by the very objective – the objective of achieving the program ultimate purpose – the production of the end product and specifically, exascale computers. Naturally, the production of all the intermediary products should comply with attaining the specified ultimate goal.

The necessity of centralized transfer pricing is stipulated by the necessity of providing financial stability in the implementation of the program and elimination of inflation risk impeding the achievement of target objectives. It should be mentioned that elimination of inflation risk is economically viable, as it removes the necessity of formation of security inflation reserve.

Naturally, the construction of the network organizational system does not in the least exclude feedback – active participation of producers of intermediate products in the development of all the above-mentioned subsystems and their joint man-

agement within the framework of direct cooperation ties with neighboring enterprises, producers and consumers of products and services.

The Subsystem for Evaluation and Control

The functioning of this system involves two mechanisms: walkthrough and centralized network control and evaluation.

Walkthrough control and evaluation are performed by producers themselves across all qualitative and quantitative parameters of work and products being manufactured – products quality, time and cost. On the results of control and evaluation measures are taken to eliminate bottlenecks detected.

Centralized network control and evaluation are carried out by a program (project) management center. It controls and evaluates correspondence of progress of all network works to the adopted network plan (production, financial, price, timing) and takes decisions that are beyond competence and resource possibilities of network contactors, for example, on adjustment of calendar and price plan of works, financial and labor resources providing removal of bottlenecks detected.

The second Level of the New System for Organizational Management of Innovation Development – the State Internetwork System for Organizational Management of Economic Development

The establishment and evolution of the information era of the development of productive forces of developed economies demonstrates totally growing economic role of the state as a participant of production process, a financial center concentrating and distributing vast resources, as well as a supervision agency and a regulator of the holy of holies of commodities production – private market with its inherent attribute – commercial confidentiality. Thus, the requirement to disclose information on transactions and property movement and strengthening of state monitoring of all property movement became an act in the USA (Dodd Frank Act [20]) and was put forward as the Basel Committee recommendations (Basel3) for all the countries of the world.

The state as economic entity theoretically has one remarkable fundamental property – **indifference to the location of getting operating profit_**(percents on state credit, profit revenue, etc.). Parochial interests, barriers do not exist for the the state. It is interested only in the amount of revenues coming to state treasury or revenues expected in the future (if we abstract from possible lobbying of private interests). Moreover, this "indifference" is strengthened by another fundamental property (which is also not realized in an optimal way) – being responsible representative of interests of all those responsible for general economic development of the country.

Such properties of the state determine its fast-growing defining role in economic development at the current stage of information technologies, and the following stage – sophisticated exaflops technologies. The very nature of information technologies reject industry parochiality, as they integrate a great many industry-specific technologies, that is, figuratively speaking, form a single engine taking all interrelated participants of common movement to the shared objective and fruits of these "pastures of heaven" – profit for all passengers from a single source.

Therefore, information era and corresponding technologies require overcoming industry partiality of interests and organizational forms, and the state is most suited for meeting these requirements to the utmost extent.

It appears that to effectively face the challenges of the Information Era – both current and coming exaflops stages – it will be necessary to set up two state organizational subsystems.

The first subsystem is the system for management and active support of the implementation of Adaptive Inter-Industry Network Organizations. It includes the development and implementation of subsystems discussed above – an integrated universally available database for search, selection and transfer pricing and formation of an inter-industry network organization adaptive to the innovation program requirements.

The second organizational system is the system for balanced anti-crisis integration of Adaptive Inter-Industry Network Organizations into the common system for regulation of the development of the country economy (the regulation of flows of material, labor and financial resources) in four basic quadrants into which the whole production cycle of the country is divided:

• Government bodies of forecasting, planning, surveillance and management of the country economic development in quadrants of reproduction process;

• Quadrant of brand new advanced production processes and technologies - super-profitable,

profitable and insufficiently profitable in comparison with existing production processes and technologies;

• Quadrant of profitable but lower-quality obsolescent production processes and technologies;

• Quadrant of ideas, R&D, design and development, as well as scientific and technological projects ready for implementation;

• Quadrant of obsolescent and non-profitable processes and technologies subject to phasing out and utilization.

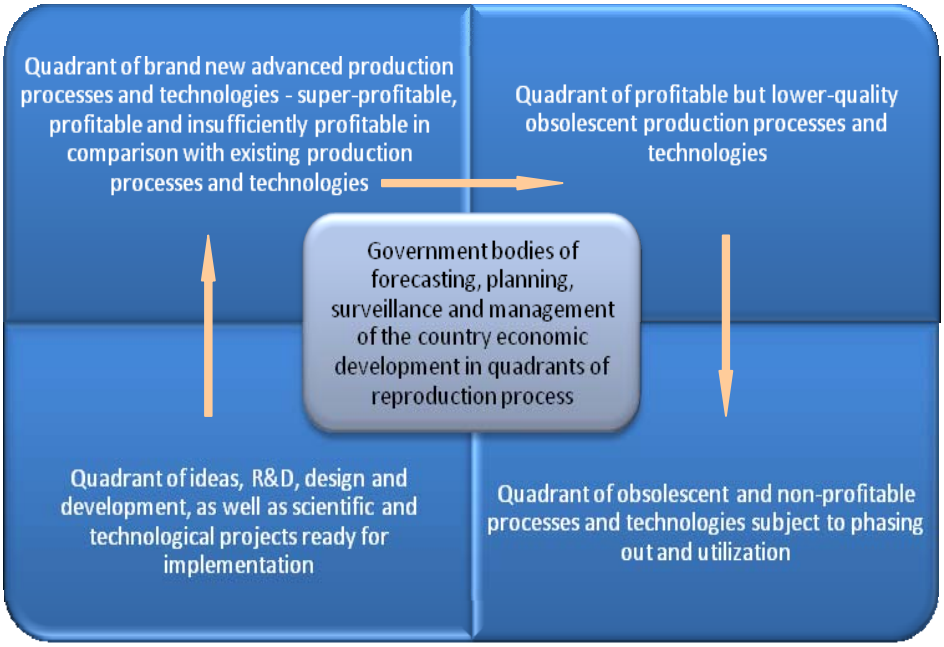

Fig. 4. Four basic quadrants into which the whole production cycle of the country

First and foremost, the pilot realization of the idea of the setting-up of Adaptive Inter-Industry Network Organization should involve the segment of complex target military and space programs.

Rationality of such approach is substantiated by the USA successful experience in the development of the sea-based missile system (at nuclear submarines) "Polaris" in 1956-1960 of the last century, the development and implementation of the Space Shuttle program in the 1960-ies (the shuttle space transportation system). Naturally, pilot implementation of other complex target programs is not excluded.

Therefore, such a launch pad should be created, but who is to do that?

It is readily apparent that it can be implemented exclusively by the state, as the national integrated database built on the basis of universal norms and standards requires a centralized approach and implementation that can cope with the intention to keep commercial confidentiality.

In 1958 the Americans took a risk and their efforts were rewarded, as they effectively used the PERT system (Program Evaluation and Review Technique) developed the same year. The US Admiralty ventured to develop and use the PERT which allowed to effectively control the activities of all companies involved (about 70 thousand works). At that time Dwight Eisenhower (1953-1961) who the US President and Neil McElroy was the Secretary of Defense (from 1957 to 1959) who doubtless were aware of this initiative and supported it, which resulted in totally new paradigm of the organization and management of production.

Will the Russian state take a risk to create the launch pad and start the pilot project of network work management (a state or public-private concern, a consortium of a new type) adapted to the implementation of a complex military or space project?

Conclusions

I. The historical process of unprecedentedly rapid development of calculating technologies approaching the level of exaflops calculating capacity, makes it possible to effectively solve the most complicated scientific and technological problems and implement production projects and programs in respect of their qualitative technical requirements, term and cost.

II. Technical, timing and cost requirements of complex projects and programs are characterized by inter-industry technological ties and dependences. In its turn, these aspects urgently require transition from dominating outdated inefficient industry-specific (trusts) system of management to inter-industry network system (adaptive inter-industry network associations, consortiums, concerns), adaptive to the requirements of modern projects and programs and integrated into the system of centralized anti-crisis regulation of the overall reproduction process of the country economy.

III. A necessary requirement of the transition to a new inter-industry type of systems of organizational management is increasing the state active economic and organizational role.

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THE PROBLEMS OF INCREASING THE SIENTIFIC AND EDUCATIONAL POTENTIAL OF RENEWABLE ENERGY

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The presence of unique reserves of hydrocarbon raw materials is not an obstacle for the development of the use of renewable energy in Russia. Large resources of energy carriers allow to avoid strategic mistakes in the selection of optimal technologies and directions of development of renewable energy sources and to create own innovative technologies and large-scale projects in Russia, using renewable energy sources. Large-scale implementation of renewable energy should be based on advanced Russia technologies.

The International UNESCO Chair «Renewable Energy and Rural Electrification» at the All-Russian Scientific-Research Institute for Electrification of Agriculture at the RF Academy of Agricultural Sciences is making a significant contribution to raising the scientific and educational potential of renewable energy in the interests of sustainable development.

Keywords: *renewable energy; innovative technologies; high efficiency solar cells; education in renewable energy.*

In 2010 renewable fuel-free energy left behind the world nuclear power both in development scale and installed capacity. A key role in the field of the development of fuel-free energy is played by photovoltaics. Experience of the Czech Republic that only in 2010 put into operation solar power plants with 1 489 GW capacity, demonstrates that neither a country scale, nor climate are not obstacles to the development of solar energy. The only condition is adequate legislation for encouragement of the use of fuel-free energy, advanced technologies and the development of own production.

Availability of unique reserves of hydrocarbon raw materials in Russia is not an obstacle to the development of solar energy (SE). Considerable resources of energy carriers allow to prevent strategic errors in selection of optimal technologies and trends of SE development and to develop own advanced technologies and large-scale projects for the use of solar energy, with due consideration for experience of Western countries, China and Japan. Large-scale development of the SE use must be based on original domestic technologies. In the field of solar energy All-Russian Scientific-Research Institute for Electrification of Agriculture (VIESH) owns over 150 patents.

95% of all solar power plants are made of silicon. Silicon content in the Earth crust amounts to 29.5% of the total mass, which is the second after oxygen, uranium content being only 0.0003%. In spite of the fact that silicon content in the Earth crust is 98300times higher than that of uranium, the price of single-crystal silicon is just insignificantly lower than that of uranium, which is accounted for by outdated faulty chlorine technology of silicon production (Siemens process). VIESH researchers have developed unique chlorine-free technologies for silicon production with low energy consumption, for which 8 RF and US patents have been obtained.

Another approach involves reduction of silicon consumption per one megawatt of capacity from current 6-8 t 3-50 times due to the use of new types of concentrators and matrix silicon solar cells (MSC).

VIESH researchers have developed and patented solar concentrators with sun tracking with 50-100 concentration, and stationary nontracking concentrators with 3-5 concentration. The both types of concentrators provide even illumination of solar photovoltaic modules which is exceedingly important in operating SPP with concentrators and MSC. Nontracking concentrators collect not only direct but also a major part of diffused (scattered) radiation within aperture angle, thus increasing SPP installed capacity and electricity output.

The third generation matrix solar cells (MSC) with 20% efficiency at concentrated solar radiation have been developed and tested at VIESH in 2009. It has been demonstrated that MSC with 6 $см^2$ area at 493 kW/m^2 illumination has electric capacity of 60 W at 15 V voltage and 4 A operating current.

A planar solar module (SM) of 36 solar cells with 125×125 mm size, connected in series, at standard test condition 1 000 W/m^2 solar radiation, 25°C temperature and 1.5 AM spectrum has the same 60 W capacity, 15 V voltage and 4 A operating current. Areas of MSC and planar SM differ 1 000 times, which means 1 000 reduction of silicon consumption per unit of power output in case of MSC with solar concentrators.

The third generation MSC are produced at the solar cells pilot technological site of VIESH. The third generation MSC technology is adapted to industrial production conditions and does not involve such labor-intensive operations as multistage diffusion, photolithography, screen-printing, vacuum metallization, etc. We have succeeded in excluding silver for making contacts, as silver consumption at global level of SC production of 30 GW exceeds 400 tons per year, which creates serious problems to the future development of solar PV industry.

The RF Federal Intellectual Property, Patents and Trademark Service have selected 100 best of 42 000 RF patents, and in this list the patent for the third generation MSC and the technology of its manufacturing has been included.

At the International Forum "High Technologies of the XXI Century" held in April, 2010, VIESH of RAAS became the Laureate of the competition "High Technologies – the Basis of Modernization of Economy and Industrial Development" and was awarded a medal for competitive project "Photovoltaic Silicon Modules with Increased Efficiency (24%) for Solar Power Plants with Concentrators".

All existing structures, materials and technologies of solar modules production provide modules service life of 20 years in tropical climate and 25 years in temperate climate with 20% capacity loss by the end of their service life. This is accounted for by ultraviolet and temperature degradation of optical polymer insulating materials – ethylene vinyl acetate and other plastics. The currently used technology of modules lamination involves vacuum processing, heating up to 150^{o}C and pressing with electric power consumption of 80 000 kWh for production of 1 MW of solar modules. In advanced technology developed at VIESH, ethylene vinyl acetate and lamination technology are replaced with filling with silicon composition and further solidification of liquid component into polysiloxane gel. Due to this process service life of solar modules is increased twice – up to 40-50 years, electric capacity is raised due to higher gel transparency and energy consumption for modules production is reduced by 70 000 kWh/MW. In addition, doubled service life raises electricity output by 20 million kWh per 1 MW of peak capacitance.

The cost of solar modules production amounts to 50% of that of solar power plants (SPP), the other 50% involves expenditures for buying grid tie inverters, metal structures and cables/ as well as for construction and installation works.

However, the use of new silicon technologies, concentrators and MSC makes it possible to build solar power plants that can compete with electric power plants using coal.

The problem of continuous twenty-four-hour and year-round electricity generation by solar power plants is the most urgent in the development of global fuel-free power industry that would be able to compete with fuel power production. VIESH researchers have offered the energy model of the future world based on the development of a global solar energy system with terawatt power exchange using solar power plants and resonant methods of electric power transmission suggested by N. Tesla.

Regional and global solar power systems able to generate and transmit energy to consumers irrespective of time of day and season have also been developed and patented at VIESH.

The global solar energy system is connected to national energy systems and comprises three solar power plants installed in Australia, North Africa and Latin America. SPP efficiency is 25%, peak electric capacity of each plant amounts to 2.5 TW and its dimensions are 200×200 km^2. The global solar power system generates electric power 24 hours a day in a uniform way all the year in the amount of 20 000 TWh/year at the level corresponding to world electric power consumption. This would allow to transfer all the coal, gas and nuclear power plants in the world to the stand-by category.

Not only SPP but other renewable energy sources (hydro, wind and geothermal energy systems) can also be used as power sources in the global energy system.

The setting-up of regional and global energy systems has already begun. The group of companies in cooperation with Deutsche Bank in Germany are planning to build a 100 GW SPP in the Sahara desert costing 400 billion EURO for electricity supply to Europe. SPP with hundreds of megawatts capacity are being built in Spain, Germany, Italy, China, the USA and Australia.

It is forecasted that the global solar energy system will be launched in 2050 and it will reach full production in 2090. In the result of the project implementation solar energy share in global electricity consumption will amount to 75-90%, while greenhouse gases emission will be reduced 10 times.

Humanity will not be threatened with energy crisis if we develop technologies for using solar energy. In this case the problems of environmental pollution with power plants and transport emissions, of provision of high-quality food products, advanced education and health care, as well as of life span increase and higher life quality will also be solved.

SPP create new jobs, improve life quality and raise energy security and independence of SPP owers due to fuel-free and distributed power generation.

The development of scientific and technological potential of renewable power generation is closely related to raising educational level and quality of training and retraining of specialists for new ecologically clean fuel-free energetics.

At VIESH of the RF Academy of Agricultural Sciences the International UNESCO Chair «Renewable Energy and Rural Electrification» has been working since 1997, and since 2003 – the chair of the Moscow State Agricultural Engineering University named after V.P. Goryachkin (MGAU).

Since 2004 VIESH has been participating in the work of the Executive Committee of European Network on Education and Training in Renewable Energy Sources (EURONETRES) of UNESCO Regional Bureau for Science and Culture in Europe (UNESCO-BRESCE).

D.S. Strebkov was appointed the chairman of the European working group for education in the field of solar energy by the EURONETRES Council decision. Under contracts with the UNESCO European Bureau the International UNESCO Chair at VIESH published the manual «Fundamentals of Photovoltaics» (292 p.) in the English and the Russian language (authors – VIESH researchers Yu.D. Arbuzov and V.M. Yevdokimov (Contract UNESCO-ROSTE (BRESKE) № 8759015 of 29.07.2005).

Under scientific and methodological guidance of the International UNESCO Chair at VIESH and the chair of MGAU textbooks for students and postgraduate students with a specialization in “Plants on the Basis of Renewable Energy Sources” have been published. Fig.1 demonstrates manuals and monographs in the field of renewable energy published by the International UNESCO Chair of VIESH [1-15].

The team of the International UNESCO Chair at VIESH has carried out extensive work related to the participation in international programs and conferences, to training postgraduates and students of MGAU, the Moscow Power Engineering Institute, the Moscow State University of Engineering Ecology, etc. VIESH in cooperation with the Moscow State University named after M.V. Lomonosov has organized three schools for young people for studying renewable energy sources and educational issues in this field.

The Chair workers obtain grants in accordance with prestigious programs (JFDP, Sustainable Energy Day, Fulbright, UNESCO, CRDF, NREL, etc.) and for trips abroad – to the USA, Italy, Austria, Hungary, Finland, Germany and Poland.

The International UNESCO Chair has developed educational laboratory benches for solar energy courses:

1. The bench for studying characteristics of semiconductor solar cells (SC) and solar modules;

2. The laboratory research bench for studying characteristics of solar radiation concentrators;

3. The laboratory research bench for simulating sun rays incidence on the Earth surface;

4. The laboratory research bench for studying photovoltaic systems.

These laboratory benches have been integrated into teaching process at the International UNESCO Chair at VIESH, at MGAU named after V.P. Goryachkin and at the Mari State University. The work for the development of laboratory

Fig. 1. Manuals and monographs in the field of renewable energy of the UNESCo Chair at All-Russian Scientific-Research Institute for Electrification of Agriculture (VIESH)

research benches has been approved by the UNESCO European Network on Education and Training in Renewable Energy Sources (EU-RONETRES**).**

The UNESCO Chair activities is reflected in published papers [16-20].

Since 1992 the Russian section of ISES-Russia of the International Solar Energy Society has been working at VIESH.

There are postgraduate and doctorate centers, as well as the Dissertation Council for Candidate and Doctoral theses defense with a specialization

Fig. 1. (*Continuation*) Manuals and monographs in the field of renewable energy of the UNESCo Chair at All-Russian Scientific-Research Institute for Electrification of Agriculture (VIESH)

05.14.08 “Plants on the Basis of Renewable Energy Sources”. Since 1997 to 2012 22 candidates and 2 doctors of engineering have been trained, including one candidate of engineering from Egypt and one candidate of engineering from Turkmenistan.

For 15 years from 1997 to 2012 the UNESCO and MGAU Chairs have published 350 research works including 24 scientific and methodological publications with total amount of 66.4 printed sheets and got 152 RF patents. Extensive work on training specialists in renewable energy has been carried out by the chairs of the Moscow State University named after M.V. Lomonosov, the Moscow Power Engineering Institute, the Saint-Petersburg State Technical University, the Moscow State University of Mechanical Engineering, the Kuban State Agrarian University, etc.

Conclusions

1. On May 26, 2010 President Barak Obama declared during his visit to the plant producing photovoltaic systems in California: “The nation that leads in the clean energy is likely to lead the global economy”.

ROSATOM states that Russian nuclear power industry is safe and does not have any alternative. In effect there exists an alternative to nuclear energetic. Difference between Chernobyl and Fukushima is that now we have advanced technologies of fuel-free renewable energy.

2. Availability of unique reserves of hydrocarbon raw materials is not an obstacle to the development of use of renewable energy sources. Considerable energy carriers resources allow to prevent strategic errors in selection of optimal technologies and trends of SE development and to develop own advanced technologies and large-scale projects for the use of solar energy with due consideration for experience of Western countries, China and Japan. Large-scale development of the SE use must be based on original domestic technologies.

3. The International UNESCO Chair «Renewable Energy and Rural Electrification» at VIESH and the Chair of MGAU named after V.P. Goryachkin are making considerable contribution to raising educational and scientific potential of renewable energy in the interests of sustainable development.

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RUSSIAN INNOVATIVE SOLAR ENERGY TECHNOLOGIES

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Dynamically developing solar energy industry based on innovative Russian technologies is an alternative to fuel energy production and in 2050 will dominate at the clean energy technologies market. By the end of the 21th century it will provide 75-90% of all the Earth demands for electric power.

Keywords: *innovative technologies; photovoltaic's; solar grade silicon; solar concentrator; matrix solar cell; solar module; global solar power system.*

Introduction

After less than 25 years after the Chernobyl disater the world witnessed the Fukushima nuclear power plant failure with exclusion zone and consequences close to those of the Chernobyl incident. Only one of the four units of the Chernobyl nuclear power plant was destroyed, and the remaining ones were operated for ten more years, and at Fukushima four units were totally demolished and will never work again. A hundred thousand people had to leave their homes. The tea factory located at 300 km to the Fukushima nuclear plant spopped to work because of radioceasium contamination of the tea plantation. The Fukushima breakdown once again demonstrated that nuclear power is far from being controlled and constitutes a real danger [1]. As a result, Germany took a decision to shut down all its nuclaer power plants by 2022. China, Italy, Venezuela and a number of other countries decided to stop the construction of new nuclear power plants at their territory.

On May 26, 2010, during his visit to the plant producing photovoltaic systems in California President Barack Obama stated: "The nation that leads in clean energy is likely to lead world economy" [2]. The US government allocated $2.36 bln from the budget to programs of raising efficiency of renewable energy sources use, including up to $500 mln. for guarantees of the loans to the RES development in the amount of $3-5 bln. They will continue financing the three innovation solar energy centers, the projects of houses with zero energy consumption and the solution of the problems of energy accumulation.

What about Russia's approach to the problem? President Medvedev stated that "there is no alternative to nuclear energy" and this statement seems to have been prepared by "Rosatom".

In fact, there is an alternative to nuclear energy. The difference between the Chernobyl and Fukushima disasters lie in the fact that today we have developed alternative technologies of fuel-free renewable energy production.

In 2010 the installed capacity of energy plants using renewable energy sources (RES) (wind, solar, geothermal and sea waves energy, bioenergy and energy produced be minihydro power plants) exceeded the installed capacity of all the nuclear power plants in the world and reached 388 GW (60 GW increase in comparison with 2009). In 2010 investments into the world renewable energy industry amounted to $243 bln., investment growth being 630% since 2004 [3]. The People's Republic of China has the lead providing 25% of all the investments in this field in the world ($54.4 bln.), Germany ranks second ($41.2 bln.) and the USA occupies the third position ($34 bln.). Wind energy is leading among other RES as to investments amounts – $95 bln.

In rates of growth solar energy industry occupies a leading position. In 2010 solar power plants with overall 22.7 GW capacity were built in the world, including 7 GW in Germany, 5.6 GW in Italy, 1.2 GW in the Chech Republic, 1 GW in Japan. The rates of growth of solar power plants production were 118% in comparison with 2009. At the end of 2011 the installed capacity of solar power plants in the world will reach 66 GW [4]. None of the other industries in the world including telecommunications and computer industry has never had such growth rate. For comparison, in 2010 in the world the construction of three nuclear power

stations with overall capacity of 3 GW was completed that had lasted for over 5 years.

To diversify the civilian sector of "Rosatom" that has high technological, scientific and production potential, it should be transformed into a Russian agency on clean energy (in Obama's terms) or a Russian agency on renewable energy (RosRE), or a Russian agency on solar energy (ROSSE). A major task of the new agency is the commercialization of advanced Russian solar energy technologies and the formation of export-oriented industry for the production and construction of environmentally safe fuel-free power plants with capacity of 10-20 GW per year which constitutes 15-30% of the world production.

The availability of unique reserves of hydrocarbons is not an obstacle to the RES development. Considerable energy carriers resources allows Russia not to make strategic mistakes in selecting optimal technologies and trends of the RES development and to develop own advanced technologies and large-scale projects involving RES use, considering experience of Western countries, China and Japan. Large-scale use of RES in Russia should be based on original advanced Russian technologies.

1. Russian innovative technologies in the field of photovoltaic solar energy

1.1. Solar grade silicon

95% of all solar power plants in the world are made of silicon. The silicon content in the Earth crust is 29.5% of its total mass, so it ranks next to oxigen, the uranium content being 0.0003%. Regardless the fact that the amount of silicon in the Earth crust exceed that of uranium by 98300 times, the cost of single-crystal silicon is just insignificantly lower that the uranium cost, which is explained by the use of outdated faulty chlorine technology of silicon production (Siemens process). The SSI VIESH specialists have developed unique chlorine-free technologies of silicon production with low energy consumption protected by 8 RF and US patents.

Another approach implies the reduction of silicon consumption from current 6-8 tons per one megawatt by 100-1 000 times due to the use of new types of concentrators and matrix silicon solar cells (MSC) developed in Russia.

1.2. Solar concentrators

SSI VIESH has developed and patented tracking solar concentrators with 100-1000 concentration, and stationary non-tracking concentrators with 3-5 concentration [5, 6]. The both types of concentrators provide uniform illumination of photovoltaic solar modules, which is extremely important in operating SPP with concentrators. Non-tracking concentrators concentrate not only direct radiation but also part of diffuse (scattered) radiation within the range of aperture angle, which raises solar energy plants installed capacity and energy production.

1.3. Solar cells

MSC developed in SSI VIESH have 20% efficiency at 50-100-fold concentration of solar radiation [5]. Bifacial planar SC and MSC patented in Russia, are transparent for inactive infrared spectrum, which reduces warming of the photo receiver and costs of its cooling. The MSC advantage is the generation of high voltage of 5-20 V per 1 linear centimeter of working area.

At the solar power plant with a concentrator with 480 kW peak capacity built in Spain within the framework of the Euclid project, series-connected planar silicon modules with overall length of 84 m were used to obtain 750 V operating voltage necessary for connecting to a transformerless inverter [7]. The length of MSC with 750 V voltage is 191 times shorter – 0.44 m and in addition, their operating current is hundred times lower than that of planar SC of similar capacity and consequently, they are characterized by low commutation losses. A MSC-based receiver of 84 m size will have 150 kV voltage and in this case a solar power plant can be connected to high-voltage DC power transmission line without any intermediary transformers, rectifiers and other converting devices.

The silicon MSC cost per unit-area is hundred times lower than that of solar cells on the basis of cascade heterostructures. The MSC technology does not require the use of silver, multistage diffusion, photolithography, screen-printing, epitaxy, texturing and other labor-intensive operations used at foreign enterprises.

1.4. Photovoltaic solar modules

All the structures, materials and fabrication technologies existing in the world, provide solar modules service life of 20 years in tropical climate and 25 years in temperate climate with 20% capacity loss by the end of life cycle. The reason for this is ultraviolet and temperature degradation of optical polymer sealing materials – ethylene vinyl acetate and other plastics. The used technology of modules lamination includes vacuum processing, heating up to 150^{o} and compressing with 80 000 kWh energy consumption per 1 MW of solar modules. In the new technology developed at the SSI VIESH, ethylene vinyl acetate and lamination are replaced with casting silicone composition with further hardening of liquid component into polysiloxane gels. As a result, solar modules service life is increased twice - up to 40-50 years, electric capacity grows due to higher gel transparency and SC operating temperature reduction, and energy consumption in solar modules production are reduced by 70 000 kWh/MW. Moreover, doubled service life increases electricity production by 20 mln. kWh per 1 mW of peak capacity.

1.5. Solar electricity cost

Minimal cost of silicon solar modules is 1 250 EU/kW at the European wholesale market and $ 1 700/kW at the American market. The cost of turnkey production of solar power plants amounts to $3 400/kW for grid companies and to $6 500/kW for houses owners [4]. In August, 2010, the US Department of Energy announced the program of the reduction of production cost of grid solar power plants down to $1 000/kW, and of production cost of solar modules – down to $500/kW by 2012. The production cost of solar modules constitutes 50% of a solar power plant cost and the other 50% include the cost of a grid inverter, metal structures, cables and of construction and installation works.

At a regional level in Italy and other countries in the world and in some regions of Russia, parity has been reached between grid electricity tariffs and cost of electricity supplied by solar power plants. For example, in Kalmykia, in the Kursk region and in some areas of Yakutia and Chukotka the electricity cost for legal entities is 7-9 roubles/kWh ($0.25-0.32/kWh), which is comparable to the current cost of electricity supplied by solar power plants. In any regions where diesel power plants are used, electrify tariffs are higher than solar electricity cost.

In the coming years silicon MSC efficiency will be raised up to 25-30% due to the use of concentrators. However, even now the use of new silicon technologies, concentrators and MSC makes it possible to make solar power plants able to meet competition with coal-fired power plants.

1.6. Round-the-clock solar electricity production

Continuous round-the-clock and all-year production of solar electricity is a major problem in the development of global fuel-free energy industry able to compete with fuel power industry. SSI VIESH has developed and patented regional and global solar energy systems providing electricity generation and supply to customers independently of time of day and seasons [5, 8].

1.6.1. Russian solar energy system

We have carried out computer simulation of a Russian solar energy system comprising two SPP installed at Chukotka and Kalinigrad (RF) or Pinsk (the Republic of Belarus) and connected to the RF unified power system. Photoactive area of solar power plants with 20% efficiency is a square with 25 km sides. Each solar power plant capacity is 125 mln. kWh. As initial data for calculation we used long-time average annual values of insolation for the areas of SPP location. This solar power system makes it possible to supply electricity in the amount of 500 TWh on round-the-clock basis for the period of 5 months from the 1st of April to the 1st of September and to satisfy all the Russia demands for electricity in this period. For two more months – in March and September, electricity can be supplied for 22 hours per day. In this case all fuel power plants will be transferred to standby category, and saved gas, oil and coal can be exported.

If a solar power system in the Kara-Kum desert is included into this power system, the amounts of electricity produced on round-the-clock basis, will be enough to supple energy to all the CIS for 6 months.

1.6.2. The Euro-Asian solar power system

The Chukotka-Lisbon Euro-Asian solar power system will make it possible to supply electricity to all the countries of Europe and CIS on a roud-the-clock basis for the period of 7 months from the 1st of March to the 1st of October.

The Euro-Asian power system is composed of two SPP with peak capacity of 1.5 tW. If a solar power plant in Tibet (Mongolia, China) and a solar power plant in Mauritania (Africa) are included into this system, round-the-clock electricity production in the amount of 6 000 tWh will be enough to supple electricity to Europe, CIS and northern countries of Asia and Africa for 7 months.

1.6.3. The global solar power system

The global solar power system is connected to national power systems and comprises three SPP installed in Australia, North Africa and Latin America. These SPP efficiency is 25%, peak electric capacity of each solar power plant is 2.5 tW and their size is 200x200 km2. The global solar power system regularly generates electricity on a round-the-clock basis throughout the year in the amount of 20000300 TWh/year at the level corresponding to the world consumption. This will make it possible to transfer all the coal, gas and nuclear power to standby category, to reduce atmosphere overheating and to halt climate changes.

As an energy source in the resonance global solar energy power system not only SPP can be used but also other renewable energy sources (hydro power plants, wind power plants, geothermal power plants, etc.).

Russia lags behind the Western countries in the development of the technology of wind blade turbines of megawatt level. However in the field of small-scale wind power plants SSI VIESH engineer S.A. Bolotov has developed noiseless wind energy plants without blades with 1-5 kW capacity and was the first in the world to organize their production. These wind power plants meet all the environmental safety requirements and in contrast to blade turbines, can work in the wind velocity range of from 3 to 50 m/sec.

For the setting-up of regional and global solar power systems new technologies have been developed in Russia that can make solar energy industry competitive considering the following criteria:

- Solar power plants efficiency should be no less than 25%.
- Solar power plants service life should be 50 years.
- Installed-cost-per-kilowatt of peak capacity of solar power plants should not exceed $2 000.
- Overall production of solar power plants should be 100 GW per year.
- Production output of semiconductor material for solar power plants should exceed 1 mln. t per year with its price not above $25/kg.
- Round-the-clock production of electricity by a solar power system.
- Materials and technologies for solar cells and modules production should be ecologically clean and safe.

The development of regional and global solar power systems has already been initiated. The Deutsche Bank and a consortium of companies are planning to set up a 100 GW solar power plant in the Sahara desert costing 400 bln. EURO for electricity supply to Europe. SPP of hundreds of megawatts capacity are being constructed in Spain, Germany, Italy, China, the US and Australia.

The global solar energy system is expected to start functioning in 2050 and will be put into full operation in 2090. In the result of the realization of this project the share of solar energy industry in the world electricity consumption will reach 75-90% and greenhouse gases emissions will be reduced 10 times.

1.7. Environmental safety of energy production

Humanity will not be threatened with energy crisis caused by the depletion of oil, gas and coal reserve if we shall master the technologies of the renewable energy use. In this case the problems of environment pollution with power plants and transport emissions, of high-quality food products provision, of education and health care, increase of life span and quality will also be solved. SPP create new jobs, improve quality of life and raise energy security and independence of SPP owners due to fuel-free and distributed power generation.

The technological processes of the SPP components fabrication are being developed wherein ecologically destructive chemical processes of etching and processing are replaced by vacuum, plasma

chemical, electro-beam and laser processes. Serious consideration is paid to the utilization of production waste, as well as to the processing of SPP components after the end of service life.

The use of SPP makes it possible to organically combine natural landscapes and environment with power plants. SPP form spatial and architectural compositions using sun-facing facades and roofs of houses, farms, trade centers, storehouses, parking garages and hothouses. At SPP territories vineyards and rosegardens can be placed and ecologically clean agricultural crops can be cultivated.

1.8. Wave-guide methods of electric power transmission

In connection with the development of unified power systems in Europe, North and South America and proposals for the setting-up of the global solar power system, the problems of transmission of terawatts transcontinental electric power flows have arisen. Alongside with the AC and DC power transmission systems, the third method can be competitive in this field: the resonant wave guide method of electric power transmission at high frequency, for the first time proposed by N. Tesla in 1897 and developed at SSI VIESH in 1995-2010 [8].

Large-scale energy companies in many countries of the world are investing vast sums and scientific resources into the development of the technology of high-temperature superconductivity for lowering Joule losses in transmission lines.

There exists another, probably more efficient method of reducing losses in main on-shore and intercontinental power transmission lines: the development of adjustable resonant wave-guide systems for electric power transmission at high frequency of 1-100 kHz which do not use active conduction current in a closed loop. A wave-guarde single-wire line lacks a closed loop, traveling current and voltage waves and there are standing (stationary) reactive capacitive current and voltage waves with 90° phase shift. Due to resonant modes adjustment and current frequency selection depending in wave length, a voltage loop and current node mode (for example, for a half-wave line) can be established in the line. Moreover, due to the absence of active current, phase shift of reactive current standing waves and 90° voltage, as well as to the presence of current node in the line, there is no need in establishing a high-temperature conductivity mode in such a line, and Joule losses are insignificant because of lack of closed loop conduction current and extremely low values of open-curcuit capacitive current near nodes of stationary current waves in the line [9].

New physics of electrical processes involving the use not of active but reactive current, will allow to solve the three major problems of modern electrical energy industry:

- the construction of extra long-range power transmission lines with low losses without the use of the superconductivity technology;
- increased transmitting capacity of the lines;
- the replacement of overhead transmission lines by cable single-wire wave-guide lines and reduction of cross-section of a current carrying conductor by 20-50 times. .

At the pilot resonant single-wire system for electric power transmission installed in the VIESH experimental hall, we transmitted 20 kW electric capacity at 6.8 kV voltage to a 6 m distance through a copper conductor with 80 μm diameter at room temperature and in this case effective current density in the conductor was 600 A/mm^2, and power effective density - 4 MW/mm^2.

Among other applications of resonant energy systems based on open-circuit current, we should mention noncontact high-frequency electric transport, the development of local energy systems with the use of renewable energy sources, the connection of off-shore sea wind power plants with shore-based substations, electricity supply to customers located on islands and in the permafrost zone, fire-safe single-wire street lighting system, as well as lighting systems for buildings and fire hazardous enterprises.

For those who doubt the existence of open-circuit currents we are citing the statements of the two outstanding scientists in the field of electric power and electric engineering.

"Extreme difficulty of correlating electromagnetic laws with the existence of open-curcuit electric current is one of many reasons why we should assume the existence of currents created by change in displacement". *D. Maxwell.*

"In 1893 I demonstrated that there is no need of using two conductors for electric power trans-

mission… Power transmission through a single conductor without return has been substantiated in practice" *N. Tesla, 1927*.

"The efficiency of the transmission can be as high as 96 or 97 percent, and there are practically no losses…When there is no receiver, there is no energy consumption anywhere…". N. Tesla, 1917.

"My experiments demonstrated that to maintain electric oscillations all over the globe several horse powers will be required". *N. Tesla, 1905*.

N. Tesla answered the question which is being often put to us: why electric power industry has not adopted his ideas? "My project was retarded by laws of nature. The world was not prepared for it. It was too far ahead of time. But the same laws will prevail in the end and make it a triumphal success". *N. Tesla, 1919*.

Solar energy industry needs state support for the realization of pilot and demonstration projects and is waiting for private capital and a new Morgan – a banker who financed Tesla's research 100 years ago.

Conclusions

Dynamically developing solar energy industry based on advanced Russian and world technologies, is an alternative to fuel energy production and in 2050 will dominate at the clean technologies market. By the end of the 21st century it will provide 75-90% of all the Earth demands for electric energy.

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INTELLECTUAL GRAPHIC IN SYSTEMS OF SAFETY OF PRODUCTION

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Modern systems of safety of production are based on the information and communication technologies including set of intellectual program complexes of support of decision-making and preparation and certification of the personnel on safety of production in computer and telecommunication networks and systems. In the course of development of decisions and static and dynamic graphic descriptions can be applied to training and certification of the personnel for safety of work as knowledge. Thus important are opportunity to form static and dynamic graphic images not - programming professional users and possibility of joint use and comparison of the graphic information resources formed by different territorially separated users.

Keywords: *intellectual program complexes of support of decision-making; preparation and certification of the personnel for safety of the production; the formalized knowledge; static and dynamic graphic images; base of graphic primitives.*

Systems of safety of production meeting modern requirements, have to include effective methods of the organization of safe working conditions, vocational training and control of knowledge of the personnel on safety of production, and also new technical means of safety of the equipment, cars, units and constructions, effective and convenient remedies of individual protection of the working. Innovative technologies of the organization of safe working conditions are based on information and communication technologies with application of the formalized knowledge and the expert methods which are built in a control system of production. Information and communication technologies of creation of safe working conditions include set of intellectual program complexes of support of decision-making and preparation and certification of the personnel for safety of production in computer and telecommunication networks and systems [1, 2].

Network intellectual program complexes of support of decision-making on safety of production develop faultless decisions in the environment of the expert systems founded on formalized knowledge which bases are increased and develop users. The intellectual program complex of support of decision-making on safety of production is understood as the set united by infocommunication process technical and software, telecommunication and computer systems and the technologies functioning in interrelation with the user (the person or group of people), capable on the basis of data and knowledge to synthesize the purposes and to develop rational faultless decisions on achievement of the objectives – to prevention (decrease) in operational injuries, incidence prevention, improvement of working conditions in electro installations.

Information (data and knowledge) of the security status of the production are formalized and collect in databases and knowledge of dynamic expert system. Resources of databases and knowledge are used for synthesizing of the purposes on achievement of safe working conditions. Means of dynamic expert system with the assistance of one user or group of network users make the decision and the operating influence, which results of action are predicted by the block of forecasts is developed and are considered at acceptance of a final decision by dynamic expert system. The complex of the interconnected information carriers having computer screen images and the corresponding software on local personal ECM and in computer communication networks and systems is used.

The most important element of the organization of safe production on the basis of information and communication technologies considers preparation and control of knowledge working on safety of work with application of the network intellectual program complexes containing formalized knowledge in text and graphic representation, and bases of this knowledge also if necessary are supplemented and develop users (responsible for preparation and certification of the personnel and trainees).

Both for decision-making on production safety, and for training and certification of the personnel for safety of work as knowledge static and dynamic graphic descriptions, in the form of means of formalization of actions and receptions can be applied at regular and emergency modes of operation of the equipment, cars, units and installations, at first-aid treatment to the victim, suppression of fires, the organization of safe production to formalization of operating influences, including with use of technological cards, models and symbolic circuits.

Static and dynamic descriptions can be considered also by one of the most effective remedies and instruments of formalization of knowledge of the highly qualified specialists accumulated in expert systems and shown in computer and telecommunication systems and networks through training computer program complexes for preparation and certification of the personnel or through operating program computer complexes at development and acceptance by the worker of the faultless decision [3].

Thus opportunity to form static and dynamic graphic images is important, using graphic primitives from the structured base of the primitives which is created previously and constantly filled up by corrected or absent primitives, in computer systems and networks not programming professional users, and also possibility of sharing and comparison of the graphic information resources formed by different territorially separated users. Lack of such opportunities significantly reduces reliability and adequacy of the graphic representations necessary in practical work on formation of safe working conditions in concrete production [4].

The block diagram of the formation of the base graphic primitives and base of graphic images as a part of the knowledge base on safety of production with automated workplace application in computer and telecommunication networks is given by not programming professional users in fig. 1.

The system of formation of base of graphic primitives 9 and bases of graphic images 10 as a part of the knowledge base on safety of production 8 turns on blocks of the network automated workplaces (1 … 6, ARM*i*), connected to the block of the user graphic primitives 7 which is connected with the block of base of the graphic primitives 9, interconnected with the block of base of graphic images 10, and both of these blocks are included in the knowledge base on safety of the production 8, connected with ARM*i* blocks. ARM*i* blocks are connected also with the decision-making block on safety of production 17 and the block of training and certification of the personnel for safety of production 18. Blocks of bases of graphic primitives and graphic images contain blocks of systematization 11, 14, specifications 12, 15 and structuring 13, 16 according to primitives and images.

The block of systematization (11, 14) is connected to the block of specification (12, 15) which is connected to the block of structuring (13, 16) connected in turn to the block of systematization (11, 14), to possibility of formation in the specialized knowledge base on safety of production of 8 consistent, mutually combined graphic elements and elementary graphic structures and the complete graphic images made of them. Optimization and harmonization of primitives 7 for the purpose of unification of fast search, increase of level of applicability and a demand is carried out when forming complete graphic images in the base of graphic images 9 included in the knowledge base on safety of production 8.

The network automated workplace of not programming labor protection specialist 1 … 6 is interconnected with each other automated workplace of ARMI in a network, in turn each network automated workplace is interconnected with blocks of the user graphic primitives 7, bases of graphic primitives of 9 and graphic images 10 on safety of production and the knowledge base on safety of production 8, decision-making blocks on safety of production 17 and training and certification of the personnel for safety of production 18. The knowledge base block on safety of production 9 is interconnected with blocks of base of graphic primitives 9 and bases of graphic images 10 on safety of production which turn on blocks of systematization 11, 14 consistently connected among themselves, specifications 12, 15 and structuring 13, 16 primitives and images respectively. The knowledge base on safety of production of system is formed as a part of expert ARM*i* systems with the corresponding software and is interconnected with the decision-making block on safety of production and the block of training and certification of the personnel for safety of production.

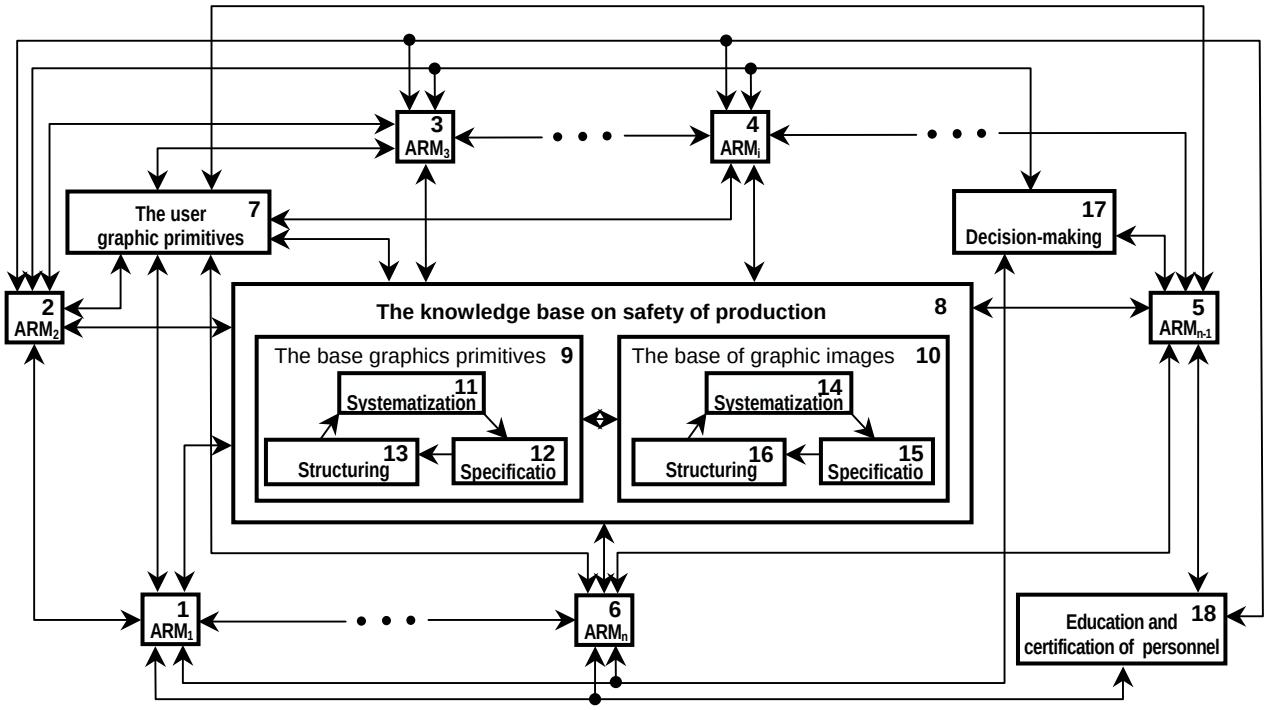

Fig. 1. The block diagram of formation of bases of graphic primitives and graphic images in the knowledge base on safety of production

On each network automated workplace from the personal ECM in the computer and telecommunication networks, equipped with the special software and interconnected with other automated workplaces not programming user fills up base of graphic primitives with the personified primitives, using the scanned graphic images, and also forming primitives in graphic editors and compiling the scanned images.

The user has the authorized access to the knowledge base on the safety of the production including productions specialized on safety of base of complete graphic representations and graphic primitives, using which resources, creates new graphic images and primitives and fills up the named bases. When forming specialized base of graphic primitives on safety of production carry out actions on systematization of primitives, including their classification, then actions on specification of primitives with allocation of subclasses, levels and elements and structuring primitives with identification of communications of elements in various levels and subclasses of primitives with the subsequent comparison of results to available primitives in the saved-up systematization and correction of the carried-out systematization.

The same actions are carried out when forming specialized base of graphic images. Intellectual graphic images build of graphic primitives, collectively coordinate, if necessary correct and place in a network database and knowledge after comparison with the finished graphic images available in it for their further use according to existing rules, requirements and other specifications and technical documentation on safety of production.

Users of an automated workplace with network software apply graphic representations from the knowledge base on safety of production with collectively verified graphic representations at development and adoption of effective faultless decisions on safety of production and at the organization of training and certification of the personnel for safety of production for formation at workers of steady skills and the abilities, allowing to prevent accidents and emergencies on production, to reduce is production the caused incidence and to improve working conditions.

An example of work of system we will review at creation of graphic primitives and images according to data on circumstances of an occupational accident, for example, electric traumas in operating time in a switchboard.

The electrical accident picture (set of static images or dynamic (animation) representation) reflects sequence of working operations correct and wrong, carried out by the main worker and actions of the worker assisting in case of defeat by a current of the main worker and impossibility to it independently to be exempted from influence of an electric current. Objects of a picture form among graphic editors with use as a construction material of graphic primitives (fragments of cars, the equipment, installations, construction objects, human bodies in their two-dimensional or volume (three-dimensional) representation in various provisions and conditions) of specialized base of graphic primitives in which are made systematization, specification and structuring primitives.

The built graphic representation contains experience and skills of the professional production worker and reflects the knowledge accumulated earlier formalized in the graphic images, placed in the knowledge base on safety of production with collectively verified graphic images (representations). Such graphic description of an occupational accident is the most effective tool when training the worker in the correct assistance in concrete accident and when forming at the worker carrying out production operations steady professional and safe for his life and health of skills.

The created specialized network base of collectively verified graphic primitives by systematization, specifications and structuring primitives on safety of production is used by the special software in computer and telecommunication systems and networks for extraction of primitives on safety of production and creation from them new intellectual graphic descriptions, thus compare these graphic descriptions with placed in the network knowledge base on safety of production and place them in this knowledge base, and specialized base of graphic primitives form previously and constantly fill up it with the corrected or absent primitives applied at formation of new visual descriptions.

Again created intellectual graphic images place in the knowledge base on safety of production after comparison to complete graphic representations and use for effective realization of these representations at decision-making on safety of production and during the training and certification of the personnel for safety of production in computer networks, and accumulate primitives for formation not only exact graphic descriptions of traumatic situations, actions and receptions at regular and emergency modes of operation of the equipment, cars, units and installations, at first-aid treatment to the victim, suppression of the fires, operating influences at the organization of safe production, but also for creation of inexact and incorrect visual images of the named situations, objects and actions, thus creation of visual static and dynamic graphic images is carried out by not programming professional users.

The technology of work of the professional user with library of collectively verified graphic primitives is similar to work of the expert with spelling and encyclopedic the dictionaries including mere verbiages, systematized on subject domains with specification on objects and actions. Typing words, the professional user describes situations and circumstances in this or that production in the form of complete semantic structures – offers. Gathering graphic primitives, he creates graphic pictures of the same situations and circumstances if semantic descriptions can be replaced with graphic representations.

Graphic representation is a graphic offer or the graphic story, and possibility of creation of incorrect graphic descriptions for their use in control training procedures is provided. The library of collectively verified graphic primitives contains also public complete graphic images which can be applied by users to editing for creation of the new graphic and dynamic pictures representing formalized knowledge of safety of production.

In considered system of safety of production with use of the intellectual graphics containing blocks connected among themselves of network automated workplaces and with blocks of the user graphic primitives and the knowledge base on safety of production, specialized network bases of graphic primitives and graphic images on safety the productions connected to blocks of network automated workplaces and with the block of the knowledge base on safety of production, with possibility of implementation of delivery of collectively verified primitives to each network workplace for creation of the new intellectual graphic images placed in the knowledge base on safety of production are executed.

There is an opportunity with application of specialized network software on each network

workplace from the personal COMPUTER to organize quick access to specialized base of the graphic primitives including the user graphic primitives, and base of complete graphic representations as a part of the knowledge base on safety of production, using which generalized resources in the form of collectively verified primitives and graphic descriptions not programming professional user creates the new graphic images reflecting requirements of the specifications and technical documentation, reproducing traumatic situations, for formalization of the operating influences training and supervising procedures, including with use of technological cards, models and the symbolic circuits, having high reliability, unambiguous perceptibility, availability to effective realization at decision-making on safety of production and by personnel preparation on safety of production.

The system allows to accumulate the knowledge formalized in the form of intellectual graphic images as some not duplicated resource of the concrete organization available at special authorization to other network users and applied as in development of decisions on prevention of operational injuries, and on prevention of the production caused incidence and improvement of working conditions. The graphic representations created by professional production workers with application of network dictionaries libraries of graphic primitives are the most effective remedy of preparation of the personnel on safety of production and the subsequent reliable control of their knowledge.

Conclusions

1. In systems of safety of production with use of intellectual graphics in computer and telecommunication networks formation of static and dynamic graphic images with use of specialized base of the graphic primitives which are created previously and constantly filled up by not programming professional users, allows to increase efficiency of decisions on safety of concrete production and preparation and certification of the personnel for safety of this production.

2. Effective replenishment by not programming professional users of bases of graphic primitives and images in the network knowledge base on safety of production by collectively verified primitives and images is provided with realization of the interconnected procedures of systematization, specification and structuring graphic primitives and images.

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VORTEX EFFECT – VORTEX ENERGY TECHNOLOGIES

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The article presents technical applications of vortex energy technologies.
Keywords: *vortex; turbulent energy; cooling systems; hydraulic heat generator; vortex wind power plant; vortex suction cleaner; vacuum pump; structured water; composite fuel.*

Regardless long-time history of research in this field, as well as practical importance of vortex flows, their general laws have not yet been researched enough. Thus, physical mechanisms of birth, origin, self-renewal and disruption of vortex flows have not yet been completely revealed, Various approaches developed within the framework of atmospheric vortices theory, vortex industrial equipment theory and magnetic hydrodynamics appear not to be enough for the construction of comprehensive theoretical model allowing to make quantitative calculations with high accuracy to explain the results of in-situ measurements and to considering multicomponent character of media, complexity and tridimensionality of processes vital for the birth, self-renewal and disruption of vortex, and non-linear character of equations describing these processes. However, even now we have some empiric algorithms of processes occurring in vortex flows and the methods of calculation of vortex devices and units, which for many decades have been used in various industrial technologies. Vortex devices are distinguished by their simplicity, lack of moving components, fast response, low weight and reliability of design. Vortex technologies are the sole case when turbulent energy is used for performing work, heat generation, absorption and formation of pressure gradients.

Vortex effect was discovered by J. Ranque in 1931. However, it is the empiric theory of vortex effect developed by Samara researcher Alexander P. Merkulov [1] in the 70's of the last century, that has provided real technical possibility to use vortex effect. Nowadays, 40-50 years later the range of developed and applied devices using vortex effect is exceedingly wide, and their possibilities and prospects are highly impressing. Hence, in some models of thermodynamic energy transformers (vortex refrigerators) temperature at the axis reaches –200°C at initial ambient temperature. Even now there exist vortex power plants using unusual possibilities of vortex effect for producing "structured water" and composite fuel, as well as for cold cracking of hydrocarbon fuel. In addition, vortex heat generators, seawater desalinating equipment and vortex power plants are currently available [2, 3].

Below we present some pilot projects in the field of vortex energy technologies.

Vortex conditioning and cooling systems (fig. 1, 2)

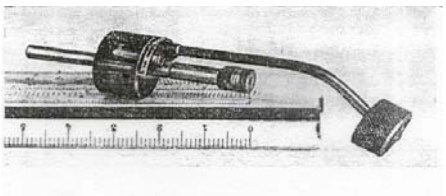

Fig. 1. Vortex micro refrigerator

Fig. 2. Vortex conditioner

Vortex conditioner technical characteristics

- air working pressure, atm	10
- air pressure at the input, atm	up to 6
- cold air temperature, °C	-55
- air consumption, m^3/min	3.0
- air consumption, l/min	40
- cooling temperature, °C	3…30
- overall dimensions, mm/mass, kg	18×50/0,15
- refrigerating capacity, kW	0.4…3.0

Automobile vortex ejector

a b

c

Fig. 3. Ejectors: a – for a river tug; b – for Zhiguli and Oka cars and motobykes; c – for a bus

Ejectors are installed at an exhaust pipe and provide increase of effective capacity of an engine by 10…12%; fuel consumption reduction by 10…15%; reduction of CO percentage by CO на 10…15% and of balance-of-plant consumption - by 10…12% (fig. 3).

Vortex hydraulic heat generator (fig. 4, 5)

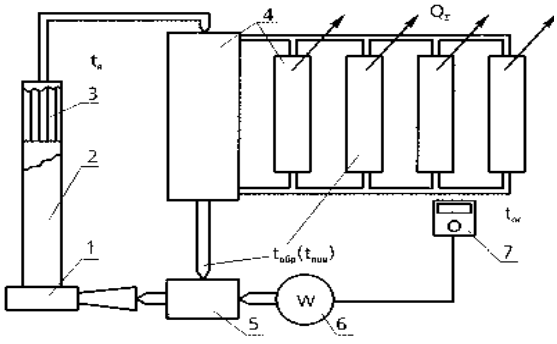

Fig. 4. The diagram of decentralized heat supply system

Fig. 5. Vortex hydraulic heat generating plant

Vortex wind power plant (VWPP)

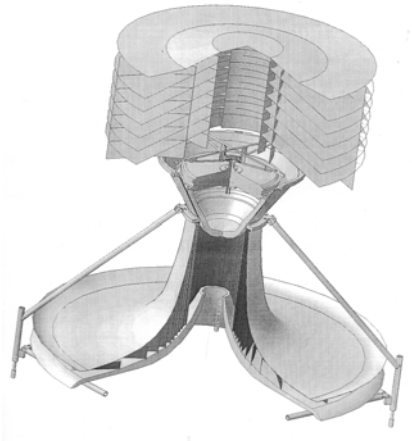

Fig. 6. VWPP general physical configuration

Fig. 7. Components of the VWPP construction

VWPP technical parameters (fig. 6, 7):

- working wind velocity, m/s – from 3…5 м/с;
- "rotor-generator" excludes a shaft and a blade wheel,
- there is no "set-up to the wind" system,
- the plant design envisages its modular assembly of identical functional modules;
- stabilization of the rotor speed is provided solely by changing the width of the plant air nozzle.

Vortex vacuum cleaners and washers. On the basis of vortex devices a brand new "vortex" method of cleaning and washing of both flat and curved surfaces has been developed (fig. 8-10).

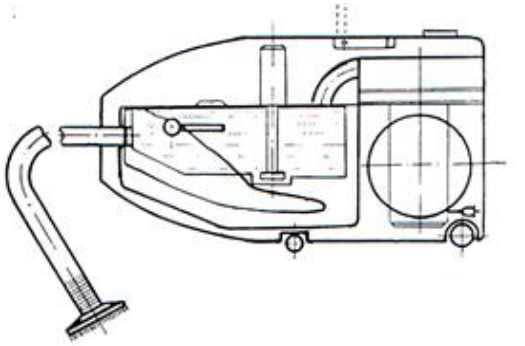

Fig. 8. Vortex washing vacuum cleaner

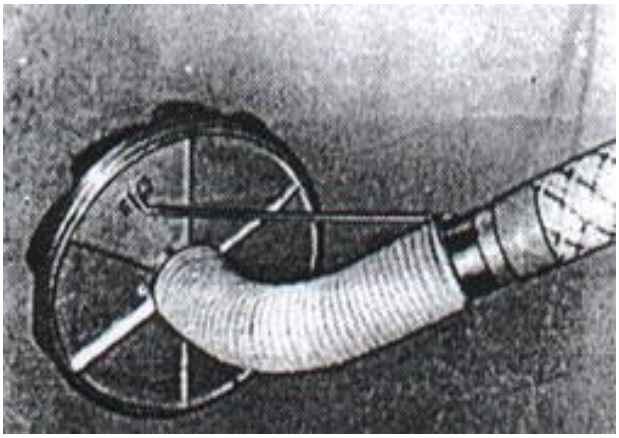

Fig. 9. Vortex washing head

Fig. 10. Device for washing airframes

Vortex vacuum cleaner. This device is based on the vortex tube characteristic to create a zone of low pressure in the near-axial area of whirled flow. The vortex vacuum cleaner peculiarities: the ability to create high rarefaction in vacuumized areas, which conventional single-stage jet ejectors are unable to perform, as well as all-mode character. In contrast to jet ejectors, it does not require change in geometric form of a nozzle and other elements while operating in a wide range of compressed gas pressures and degrees of pressure of media being vaccuumized (fig. 11).

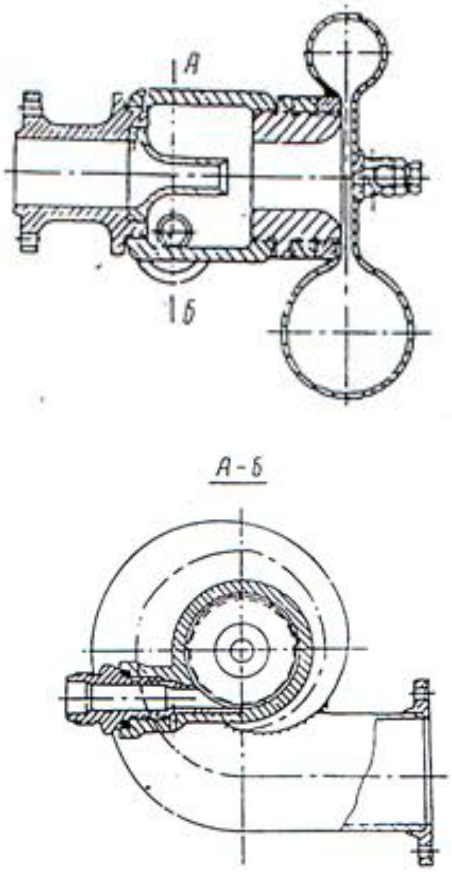

Fig. 11. Vortex vacuum cleaner configuration

Seawater desalination. Desalination is carried out through water treatment with the use of hydro-vortex cavitation. The suggested desalination method ensures:

- heating and separation of saline water in a single unit;
- high pressure generation in flow of water being desalinated through water rotation at high speed.

The pilot plant provides separation of admixtures and salt forcing them out to upper layers of flow being separated. The plant operation results: salt concentration is reduced 300…400 times; energy consumption in the process of producing fresh water is 1.3…1.5 times lower than when using vacuum distillation; production cost of desalinated wa-

ter is approximately twice lower in comparison with known desalination methods (fig. 12).

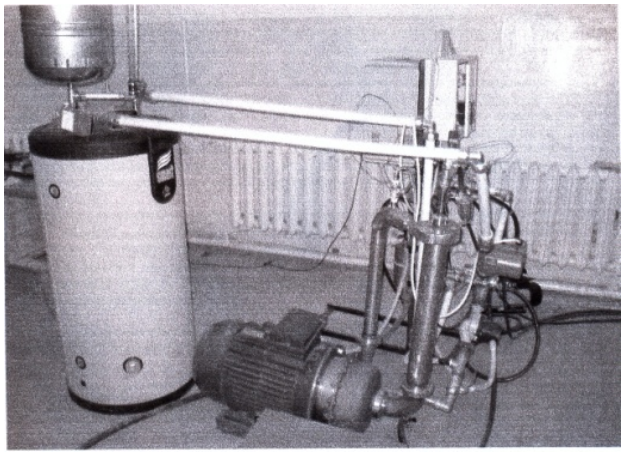

Fig. 12. Seawater desalination unit

Production of structured water with the use of hydro-cavitation units (fig. 13, 14)

Fig. 13. Rotary-pulsed unit

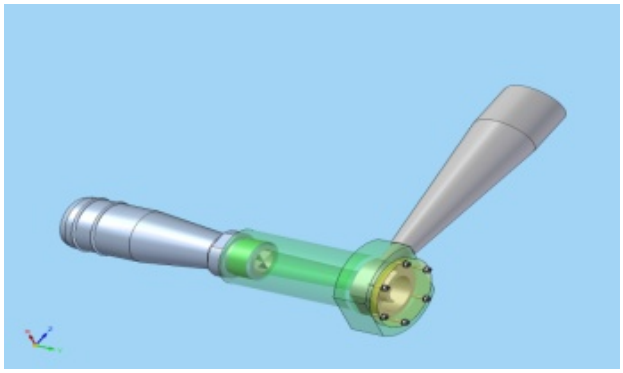

Fig. 14. Cavitator

Structured water is water whose structure is similar to that of water in blood, lymph and intracellular water plasma: clean, easily absorbed (degree of superficial tension among water molecules is about 43 dyne/cm), weakly alkaline (pH>7), its water oxidation-reduction potential is from -100 to -200 mV. Vortex hydro-cavitation units make it possible to obtain structured water directly from tap water, at the same time cleaning it from solid particles and biosolids. These units can produce water with required (specified) parameters.

Composite fuel production (fig. 15, 16)

Fig. 15. Rotary-pulse unit

Fig. 16. Vortex hydro-cavitator

Fig. 17. Comparison of emissions in the process of combusting mazut and composite fuel

To produce combined activated fuel (composite fuel) hydro-cavitation and rotary-pulsed units were used (fig. 17). The operating principle of these activators is based on intensive intermixing of various hydrocarbons and water at molecular level through vortex movement and cavitation. Composite fuel is a composition of hydrocarbon fuel with water in various ratios. This provides a principally new type of liquid fuel differing from hydrocarbon fuel by peculiarities of burning-out and heat exchange. In the process of compounding of hydrocarbon fuel and water at molecular level, water becomes a sort of catalyst improving fuel combustion process. Composite fuel (composition: 60% of diesel fuel and 40% of water) has by far higher combustion value (11 000 kcal/kg(m^3) than diesel fuel (10300 kcal/kg(m^3) and higher cetane number - “53” in comparison with “35” for diesel fuel. In addition, it contains half as much sulphur and harmful emissions into the atmosphere in combustion process are reduced (soot by 30…50%, CO and NO 2…3 times) .

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THE VORTEX WIND POWER PLANT

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The article presents the materials on the development of the power plant transforming ram wind flow into swirling jets making it possible to use low winds and low-potential upward heat flows.
Keywords: *wind energy; wind power plant; air flow; upward air currents; vortex.*

The vortex wind power plant (VWPP) can use low-potential air currents moving in the atmosphere and water areas with 3-4 m/sec velocity, utilize heat flows discharged into environment by industrial enterprises, as well as to transform solar and geothermal energy in the form of thermo-induced upward air currents (fig. 1). This plant transforms uniform wind flow into vortex-like currents, concentrates wind power and organizes and accumulates wind energy and low-potential thermal flows, in the same way as in natural conditions wind kinetic energy distributed in large space, is concentrated to extremely high degree in a compact nucleus of a tornado.

The wind power plant can be automatically adjusted to real velocity of ram air flow at calculated values of rotation speed of the electric generator of the wind power plant, which provides high-efficiency energy transformation with a wider range of wind velocities. Existing wind power plants have operating range of wind velocities from 6-15 m/sec to 20-25 m/sec. VWPP makes it possible to expand operating range of wind velocities from 3 m/sec to 60 m/sec and more, primarily due to modular construction of wind converters **(**fig. 2 – 5).

The VWPP advantages in comparison with conventional wind motors:

- size, weight and operational wind velocity are 1.5 – 2 times lower;
- generator-rotor does not have any shaft and the “setup for the wind” system;
- the plant configuration is modular – it is assembled of identical functional modules;
- stabilization of rotor speed is provided by changing the area of the plant air intake;
- wind energy efficiency is ξ~0,3;
- specific speed Z = 1.5 – 2,0.

Fig. 1. Pilot VWPP

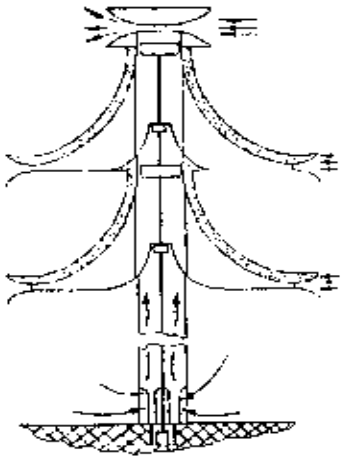

Fig. 2. VWPP modular configuration

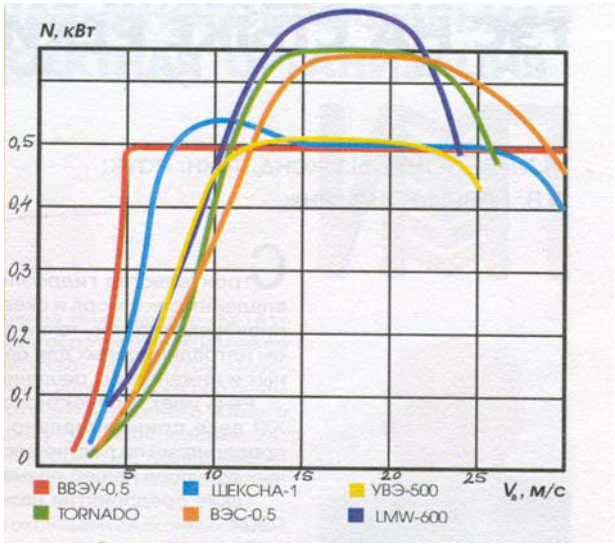

Fig. 3. Comparative characteristics $N=f(V_в)$ of bladed wind power plants and VWPP

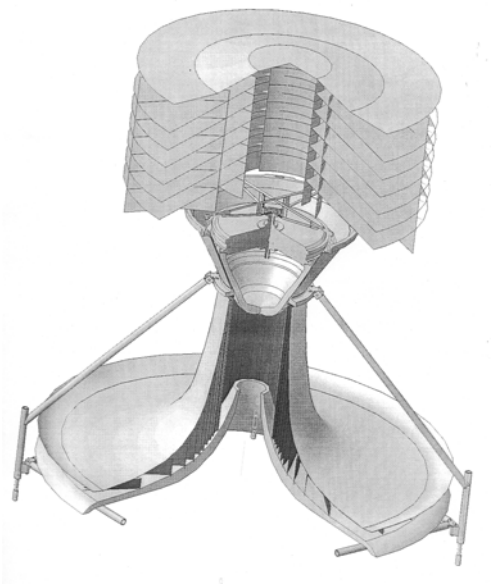

Fig. 4. The VWPP experimental model

Fig. 5. Components and assembly units of the VWPP experimental model

Ecological Evaluation of the Vortex Wind Power Plant

All over the globe wind power engineering is rapidly developing. However, in its development it has to overcome multiple difficulties, both objective (high clean energy cost; low density of energy per unit area of a wind wheel; unpredictable changes of wind velocity throughout the day and season, requiring stand-by power plants or generated energy accumulation; adverse effect on live environment of humans and animals, on TV-communications and bird migration paths) and specific – the necessity to obtain numerous permissions, including those from communications and civil aviation agencies and military departments. Large stationary **bladed** VWPP (over 20 kW capacity) have adverse effect on TV-signals. At the distance of up to 0,5 km they cause TV-signals disturbances. This is due to the fact that the blades of the WPP wind wheel reflect a signal thus causing disturbances in TV-signal transmission. In such WPP operation enough infrasound is produced to affect humans and animals. Moreover, during large WPP operation natural noise from wind wheels emerges. That is why the installation of WPP with capacity over 10 kW is unacceptable within the limits of a city or a settlement. They should be installed at safe distance from populated areas (0.5 – 1.0 km). For many years flight dispatchers have been complaining that stationary bladed wind power plants appear on their radars screen and interfere with their work not only because of their presence but because of generating the so-called "shadows", reflected on the screen as long lines. In these "shadows" which can reach several hundred meters, radar stations cannot detect any objects. A signal from wind power plants can differ in intensity depending on weather factors, angle of deflection and rotation frequency of a wind power plant rotor. The vortex wind power plant is configured in such a way that the rotor is located inside the plant frame, that allows to easily screen low-frequency audio noises of the rotor. There is a whole variety of technologies of using sound and noise absorbing coatings and they are widely applied in aeronautical equipment and radar stations.

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THE VORTEX GAS-WIND TURBINE

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In this paper the operating principle and design solution of vortex gas-wind turbine to generate electricity through the use of the effluent gas from the gas compressor units and kinetic energy of the wind are considered.

Keywords: *gas compressor unit, loss of electricity, gas-turbine power units, wind energy, vortex wind power plant, exhaust gases, combined gas-wind power plant.*

To satisfy balance-of-plant needs of each of hundreds of gas compressor stations equipped with gas pumping units approximately 1.5 – 2.5 MW of electric power are consumed. Electric power is supplied to gas compressor from high-voltage power transmission lines located at a distance of tens and hundreds of kilometers from them. In this process, losses during transportation and transformation of electric power supplied on a centralized basis, generally constitute 10 – 15 % of electric power consumed for compressor stations balance-of-plant needs and in general reach impressive amounts in Russia. To raise reliability and provide emergency power supply, all the gas compressor stations are equipped with special emergency stand-by gas-turbine power units [1]. In the context of continuous increase of cost of electric power supplied on a centralized basis, as well as gas transportation costs, it is appropriate to make efforts to reduce and even eliminate the gas compressor stations dependence on expensive energy supply from external sources. It should be mentioned that one of possible approaches is equipping gas-turbine compressor stations with efficient energy-saving gas-turbine or gas-vapor stand-by power units, thus rejecting inefficient stand-by equipment. However, this approach will demand heavy capital expenses.

Another way is to generate electricity with the use of wind energy to satisfy BOP needs of gas compressor stations. Yet the majority of bladed wind power generators installed at towers 30 – 40 m high, with the wind wheel blades 4 – 5 m long and horizontal axis develop power of approximately 800 – 1000 kW at average wind velocity of 5 – 7 m/sec. Relative capital investment into these wind power plants are in the range of 1 200 – 1 400 $/kW. High cost and the possibility to obtain required capacity only in areas with high wind load make them inefficient for satisfying compressor stations balance-of-plant needs.

Vortex wind power plants have by far lower cost [2]. In their hyperbolic frame (stator) whirling air flow is formed that is similar to natural tornados having considerable kinetic energy store. In near axial central area of vortex formed in a stator, pressure is lowered in comparison with external atmospheric pressure. Due to this factor additional air flow mass is sucked into upward tornado-like column. In the wind wheel of this wind power plant having a vertical axis, kinetic energy of air flow is transformed into mechanical work utilized for electric power generation. Vortex power plants operating at by far lower wind velocity (2 – 3 m/sec) and having similar areas swept by the wind wheel, can develop power which is five-fold higher than that of bladed wind power plants with a horizontal axis.

Waste pipes of gas pumping units of gas compressor stations every second emit millions of kilograms of waste gases into the atmosphere at velocity of nearly twenty meters per second and at temperature of up to 400 ° C.

In addition, kinetic energy of exhaust gases of gas pumping units is comparatively low and practically does not allow to use their considerable energy potential directly for electric power generation and satisfaction of balance-of-plant needs of gas compressor stations. As speed and kinetic energy of exhaust gases increase, resis-

tance of exhaust line is raised and absolute efficiency of gas pumping units is reduced. Therefore, the creation of power plants designed to satisfy balance-of-the plant needs of gas compressor stations through the development of new types of vortex combined gas-wind power units with vertical axis and the possibility to effectively use energy potential of exhaust gases flows of gas compressor stations and kinetic energy of ram wind flow, is of utmost interest.

Depending on consumption and temperature of exhaust gases of gas turbines of compressor stations, even in calm weather electric capacity of gas-wind power plants can amount to from 80 to 200 kW. Moreover, as wind velocity increases, vortex effect is intensified and, consequently, the plant capacity is raised.

Figura 1 demonstrates the basic diagram of movement of flows of exhaust gases of gas compressor stations, and atmosphere air in the gas-wind power plant. The plant of this type is equipped with an input swirler of air flow, causing its vortex motion accompanied by increased tangential velocity, rarefaction in the vortex axial part and accelerated movement of flow of exhaust gases of gas pumping units. Preliminary whirled gas flow coming from the exhaust pipe of a gas compressor station is fed to the central part of the cylindrical stator of the gas-pumping unit and is mixed with air flow, thus being accelerated with it.

Due to the fact that in the axial part of the stator of a gas-wind power plant minor rarefaction is formed in relation to atmospheric pressure, there will be no gas-dynamic impedance of the exhaust line, as well as reduction of absolute efficiency of the gas turbine or the gas pumping unit capacity.

If tangential component of whirled gas-air flow dominates at the hyperbolic stator periphery, in its central part axial flow velocity is considerably increased.

It is important that as wind velocity in the gas-wind power plant increases, vortex effect is intensified alongside with increased velocity and higher gas-air mixture consumption, thus raising the plant capacity.

Construction diagram of the gas-wind power plant is presented at fig. 2. The plant frame has hyperbolic shape and is installed with air gap under the exhaust pipe of the gas-pumping unit.

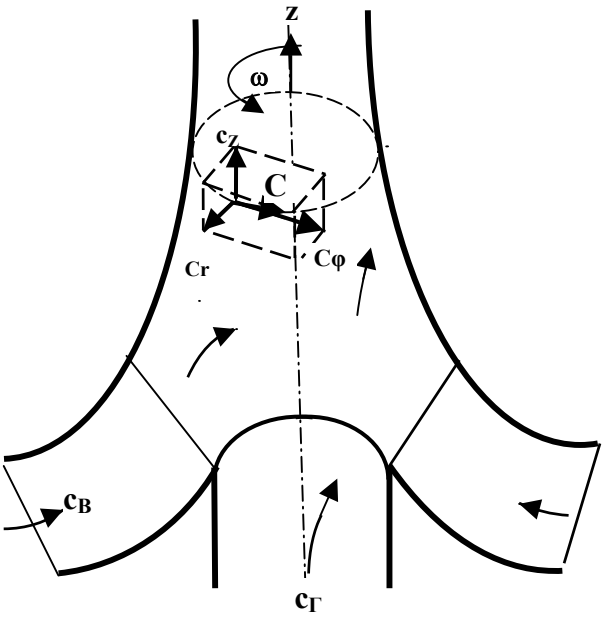

Fig. 1. The diagram of gas-air flows in the plant stator:
C_B, $C_Г$ – air and gas flows velocities at the inlet of the gas-wind power plant; C – absolute velocity of gas-air flow at the stator walls; C_Z, Cr, Cφ – velocity C projection on the coordinate axes; ω and z – tangential and axial velocities of gas-air flow

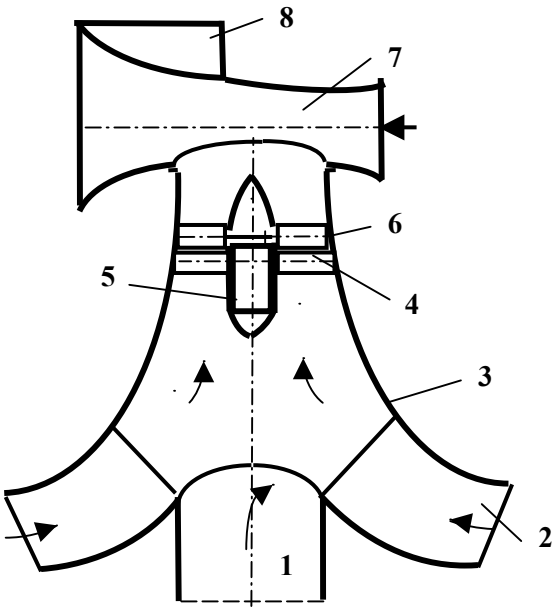

Fig. 2. The block diagram of the gas-wind power plant of the gas pumping unit:
1 – exhaust pipe; 2 – curvilinear air channels; 3 – hyperbolic stator; 4 – guide vanesт; 5 – electric generator; 6 - axial turbine blades; 7 - Venturi tube; 8 - weathercock

With the use of curvilinear guide blades 2 air wind flow is whirled, increasing its tangential velocity, and fed into the plant hyperbolic stator 3 wherein it is mixed with preliminary whirled gases coming from the exhaust pipe 1 of the gas pumping unit. With the use of a guiding device 4 gas air flow accelerated in the plant hyperbolic frame, is fed to the blades of the axial turbine 6 driving the electric power generator 5. Under the outlet part of the stator 3 the Venturi tube is installed on bearings, thus producing additional rarefaction in the upper part of the plant frame. With the use of a guide plate 8 (vane) the Venturi tube is installed in the direction of the wind which enhances capacity of the axial turbine 6 and the electric power generator 5.

Conclusions

The operating principle and construction diagram of the gas-wind plant make it possible to effectively utilize energy of exhaust gas flows of the gas pumping units and kinetic energy of ram air flow for electric power generation.

In addition, it is characterized by the following advantages:

- higher speed and kinetic energy of gas-air flow;

- higher mass flow through the axial turbine;

- dilution of hot exhaust gases of the gas pumping unit with air flow, reduction of temperature of gas-air mixture and of harmful substances concentration therein, which allows to reduce the height of the gas pumping units;

- due to the use of Venturi pipe, in the exhaust pipe of the gas pumping unit minor rarefaction is formed thus reducing hydraulic losses in exhaust duct and increasing absolute efficiency of the gas turbine with the same capacity of the gas pumping unit;

- major advantage – due to independent electric power supply to satisfy BOP needs the reliability of the operation of gas compressor station at main gas pipelines will be increased;

- if gas-wind power plants are installed at gas-pumping units in combination with centralized electricity supply, expenses for buying electricity from outside suppliers will be considerably reduced, and it will be possible to reduce fuel gas consumption by stand-by gas-turbine power plants.

It is essential that a major part of gas-pumping units of gas compressor stations located at great distance from power plants and transit high-voltage power transmission lines can be equipped with gas-wind power plants of this type.

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