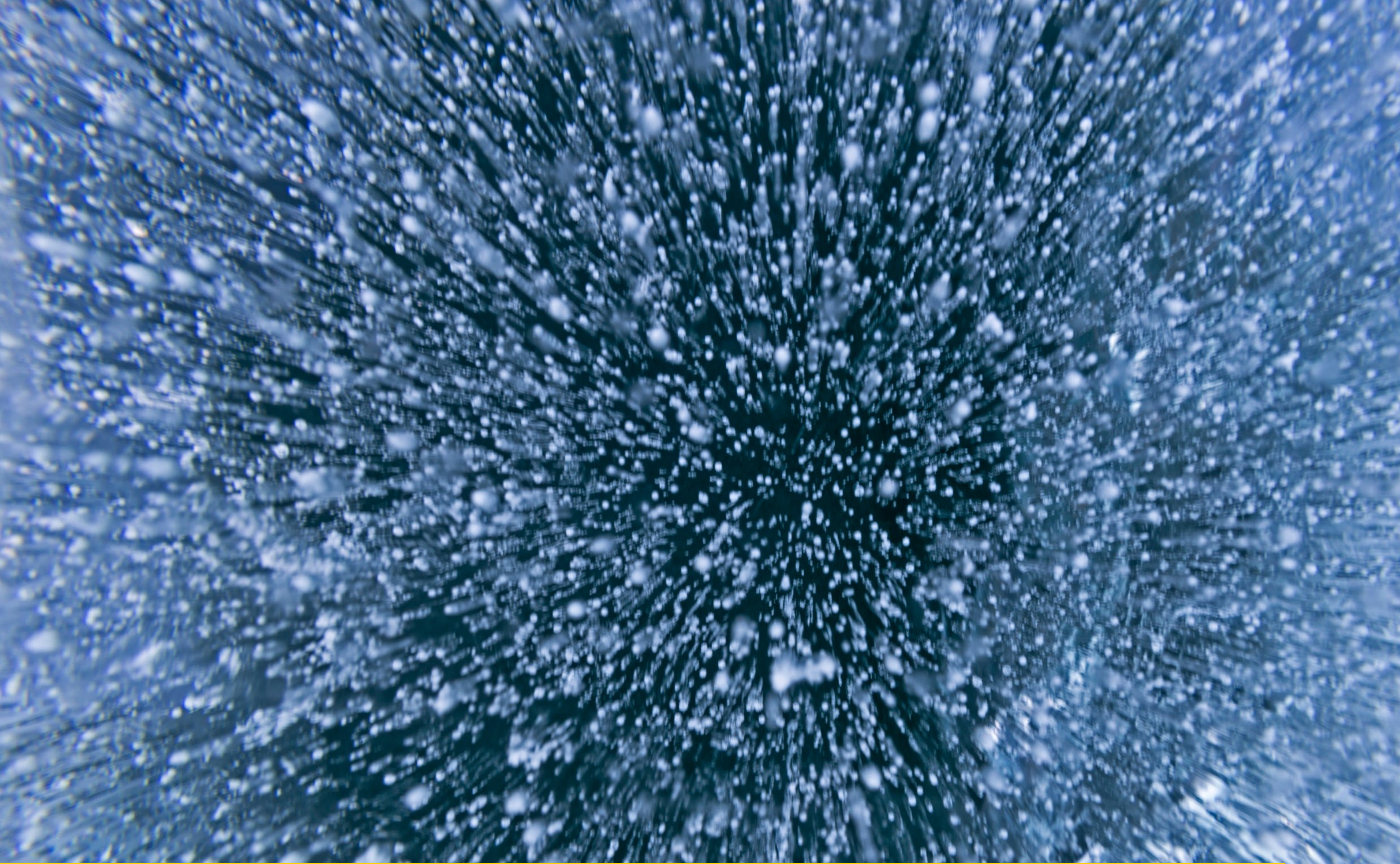

Critical Infrastructures in the Digital World

IWCI 2022

PROCEEDINGS & PROGRAMME OF THE INTERNATIONAL WORKSHOP

March 16 – 21, 2022
Bolshoe Goloustnoe

CRITICAL INFRASTRUCTURES IN THE DIGITAL WORLD-2022 WORKSHOP PROGRAMME

March 16 **Wednesday**

Departure from Irkutsk at 10:00

Arrival in the Bolshoe Goloustnoe

March 16, 17:00 **Wednesday**

Registration of participants

March 16, 20:00 **OPENING CEREMONY**

Welcome Party

March 17, 10:00 **Thursday**

SESSION 1

1. Main trends in the development of artificial intelligence on the example of their application in energy sector / **Massel Liudmila** *(Melentiev Energy System Institute SB RAS, Irkutsk, Russia)*
2. The digital platform for development of intelligent services for assessing risks of organizm critical conditions / **Gribova Valeria, Petryaeva Margarita, Shalfeeva Elena** *(Institute of Automation and Control Processes FEB RAS, Vladivostok, Russia)* ***(on line)***
3. Knowledge bases engineering for semi-automated formation of aviation task cards based on event trees transformations / **Dorodnykh Nikita, Nikolaychuk Olga, Yurin Aleksander** *(Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk, Russia)* ***(on line)***
4. Technology of innovative energy development forecasting based on intelligent data analysis **/ Kopaygorodsky Alex** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
5. Ontological and cognitive modeling in the study of resilience of socio-ecological and energy systems / **Pesterev Dmitriy** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*

Round table "Artificial intelligence: prospects and directions of development"

Keynote Speakers: **Liudmila Massel, Valeria Gribova, Olga Gerget**

March 17, 17:00 **Thursday**

1. Research of interrelations of energy and socio-ecological systems using semantic technologies / **Vorozhtsova Tatyana, Ivanova Irina, Maysyuk Elena** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*

Round table "Ontological space of knowledge in the field of energy and ecology: the need for creation and approaches to implementation"
Keynote Speakers: **Liudmila Massel, Tatyana Vorozhtsova, Galina Zagorulko**

March 18, 10:00 **Friday**

SESSION 2

1. Mathematical modeling of plasma flow at low pressures in vacuum chamber with charge on body **/ Shemakhin Aleksandr[1], Zheltukhin Victor[1,2], Shemakhin Evgeny[1]**
   [1]Kazan Federal University, Kazan, Russia
   [2]Kazan National Research Technological University, Kazan, Russia
2. Study of the operation of a self-tuning predictive speed controller of a synchronous generator on a cyber-physical model / **Bulatov Yury[1], Kryukov Andrey [2,3], Suslov Konstantin [3]**
   [1]Bratsk State University, Bratsk, Russia
   [2]Irkutsk State Transport University, Irkutsk, Russia
   [3]Irkutsk National Research Technical University, Irkutsk, Russia
3. The use of digital technology in buildings is a way to decarbonize the energy sector / **Galperova Elena** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
4. Two-level technology for studying energy security threats using cognitive modeling methods and linear optimization models / **Pyatkova Natalia, Massel Aleksei** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
5. Development of models for analyzing threats to the Industrial Internet of Things in the energy sector **/ Gaskova Daria** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
6. Analysis of approaches to medium-term forecasting of earthquakes based on fuzzy logic methods **/ Kuklin Egor** *(Irkutsk National Research Technical University, Irkutsk, Russia)* ***(on line)***

March 18, 17:00 **Friday**

1. Preventive analytics in safety tasks for critical infrastructures development / **Fridman Alexander** *(Institute for Informatics and Mathematical Modeling FRC KSC RAS (Apatity, Murmansk region, Russia)* ***(on line)***

DISCUSSION

March 19, 10:00 **Saturday**

SESSION 3

1. On the problems of route constructing and object locating in a dynamic environment / **Lempert Anna, Kazakov Alexander** *(Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk, Russia)*
2. A web-based software system for intelligent support in modeling and forecasting the water / **Stolbov Alexander, Lempert Anna, Pavlov Alexander** *(Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk, Russia)* ***(on line)***
3. Mathematical modeling of different aspects of agricultural production under climatic and biological risks / **Ivanyo Yaroslav, Petrova Sofia, Kolokoltseva Irina** *(Irkutsk State Agrarian University named after A.A. Ezhevsky, Irkutsk, Russia)*
4. Models of management of agricultural production on lands with different fertility / **Ivanyo Yaroslav, Kovadlo Ilya** *(Irkutsk State Agrarian University named after A.A. Ezhevsky, Irkutsk, Russia)*
5. Data monitoring for information system for visualization forecasting and planning activities of agricultural producer / **Baymakov Aleksandr, Barsukova Margarita, Zamaraev Aleksei, Ivanyo Yaroslav** *(Irkutsk State Agrarian University named after A.A. Ezhevsky, Irkutsk, Russia)*
6. Comprehensive assessment of the mutual influence of energy and socio-ecological systems / **Maysyuk Elena** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
7. Information and Computing System for Energy Objects Impact Assessment on Environment **/ Kuzmin Vladimir** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
8. Non-convex optimization problems: classification and applied statements **/ Gornov Alexander, Zarodnyuk Tatiana, Anikin Anton, Sorokovikov Pavel** *(Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk, Russia)*

March 19, 17:00 **Saturday**

1. Elements of mathematical support in modelling situational awareness **/ Tuchkova Natalia** *(Federal Research Center "Computer Science and Control" RAS, Moscow, Russia)* ***(on line)***

DISCUSSION

March 20, 10:00 **Sunday**

SESSION 4

1. Information model of a residential Smart House **/ Erzhenin Roman** *(SPC "Gosuchet", Moscow, Russia)*
2. Modeling and control in energy systems based on digital twin's technology / **Massel Aleksei** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
3. The digital twin of the demand response aggregator / **Kolosok Irina, Korkina Elena** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
4. Integration of cognitive and mathematical modeling based on ontologies in Software INTEC-A **/ Mamedov Timur** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
5. Development of the digital twin of wind power station: problem statement **/ Massel Aleksei, Shchukin Nikita, Tsybikov Aleksei** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
6. Weather forecast using LSTM model **/ Tsybikov Aleksei, Shchukin Nikita** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
7. Data imputation and time series forecasting for the digital twin of a solar power plant **/ Losev Aleksei** *(Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia)*
8. Digital Twin of socio-ecological system: formulation of the problem **/ Gavrilovskii Dmitrii** *(Irkutsk National Research Technical University, Irkutsk, Russia)* ***(on line)***

March 20, 17:00 **Sunday**

Round table "Architecture of the IT-infrastructure for research in the energy sector using Digital Twins and Smart Digital Twins"

Keynote Speakers: **Aleksei Massel, Liudmila Massel**

FINAL DISCUSSION

CLOSING CEREMONY

March 21, 10:00 **Monday**

Departure of the participants to Irkutsk

Information about the scheduled Zoom meeting.

Time zone: Irkutsk, Ulaanbaatar
17 march 2022. 10:00 (1st session), 17:00 (2nd session)
18 march 2022. 10:00 (1st session), 17:00 (2nd session)
19 march 2022. 10:00 (1st session), 17:00 (2nd session)
20 march 2022. 10:00 (1st session), 17:00 (2nd session)

Download and import the following iCalendar (.ics) files to your calendar system
https://us02web.zoom.us/meeting/tZUqf--upj4rHdTqfHhn9XXY5PC7un1lK9kR/ics?icsToken=98tyKuGpqTMsHNyQsR6HRpwcB4qgM-7xiCVcgqdpjRnNCy4KWjvPY9JhZadxQdT7

Join a Zoom meeting
https://us02web.zoom.us/j/81786685170?pwd=WWNyOU1obWY0VDl3M2E1SWk4c015Zz09

Conference ID: 817 8668 5170
Access code: 123

WORKSHOP PROCEEDINGS

MAIN TRENDS IN THE DEVELOPMENT OF ARTIFICIAL INTELLIGENCE ON THE EXAMPLE OF THEIR APPLICATIONIN ENERGY SECTOR

Massel Liudmila

Melentiev Energy System Institute SB RAS, Irkutsk, Russia

Recently, there has been an increased interest in the use of artificial intelligence methods in the energy sector, due to both the main trends in the development of the energy industry (smart energy, digital energy, smart digital twins, etc.) and the success of using machine learning (ML) to solve a number of problems [1].

The report compares the terms "automation, informatization, digitalization" and highlights 5 differences between automation and digitalization: the degree of integration of processes and data, the virtualization of the main production facility, the nature of data management, the procedure for managing production, the flexibility of corporate culture. It is concluded that automation is an integral part of digitalization, but not a synonym for this term. Three areas of digital transformation identify: digital economy, digital government and the creation of high-tech infrastructure (digital space). The work of the team headed by the author[1] is mainly associated with the latter direction.

The concept of "intelligent integrated energy systems (IES)" is considered [2]. It is emphasized that in these systems the role of artificial intelligence systems and their adaptation to new tasks is increasing. It is noted that after the approval and development of the concepts of the digital economy and digital energy, the concepts of digital and smart energy, as a rule, are considered synonymous, although, in theory, digital energy should be the foundation of smart energy. The main digital technologies in the programs "Digital Economy" and "Digital Energy" are listed, one of which are "neurotechnologies and artificial intelligence".

The analysis of artificial intelligence (AI) methods used and promising for use in the energy sector is carried out from the point of view of the Digital Energy program. The reasons for the "hype" in the field of machine learning are considered. In particular, one of the reasons is the inaccuracy of the wording in the decree of the President of the Russian Federation ("On the development of artificial intelligence in the Russian Federation", 10.10. 2019), related to the role of ML in the development of AI (success of ML “allows us to talk about the appearance of AI”). Two main directions of AI development define: 1) semantic representation of knowledge - semantic technologies, expert systems; 2) related to data processing (extraction of knowledge from data) - data mining, machine learning.

Definitions of modern trends in the development of AI introduce “explainable AI”, “strong and weak AI”, “general AI”, “and trusted AI”. The concepts of “digital twins”, “smart digital twins” and “edge computing” and their applications in the energy sector describe. The ethical risks of AI and the documents adopted in this area in Russia and in the world are considered [1].

Acknowledgements. The research is carried out within the framework of the project under the state order of the MESI SB RAS, topic № FNEU-2021-0007, project № AAAA-A21-121012090007-7

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[1] Department of "Artificial Intelligence Systems in Energy" in Melentiev Energy Systems Institute of SB RAS

THE DIGITAL PLATFORM FOR DEVELOPMENT OF INTELLIGENT SERVICES FOR ASSESSING RISKS OF ORGANIZM CRITICAL CONDITIONS

Gribova Valeria, Petryaeva Margarita, Shalfeeva Elena

Institute of Automation and Control Processes FEB RAS, Vladivostok, Russia

Numerous digital platforms (ZIIoT, DataMall, OpenFMB, etc.) are created and used to form tools and services for managing cases, health, and safety. Portals, Ecosystems, Artificial Intelligence Platforms are built on them, which provide the construction of various services and digital objects, the generation of new knowledge based on big data.

As for the “medical platforms” (Synaps, SberKorus, Health Heuristics, scientific and educational platforms, etc.), the range of their applications has already gone beyond the boundaries of collecting medical data and electronic document management, and is starting to fragmentarily support of individual subtasks of doctors, experts, and conducting clinical, observational or retrospective studies. But none of the medical digital platforms has yet provided such a semantic structured model of information that would allow you to create any required software explanatory services that help solve important medical problems using the meaning of data on the changing state of the body accumulated in electronic medical records.

Both specialists and the intelligent systems, that help them, use explicitly (transferred) knowledge and experience. Medicine is characterized by variability of knowledge. The approach to Artificial Intelligence systems creation and maintenance should take into account this feature. Knowledge is obtained by different methods, and in order to be assessed for reliability, it must be formed in a form understandable to specialists. Two decades have shown that formal ontologies are the most adequate structural basis for creating and filling declarative knowledge and data bases. The architecture of the modern continuously developing intelligent system is an extension of the traditional architecture: ontology, ontological knowledge base, fact base, ontological problem solver, intelligent graphical interface. An ontology-oriented solver interprets a formalized ontological knowledge base.

The cloud computing IACPaaS platform is intended for support of development, control and remote use of such intelligent systems and services. The paper shows what kind of ontology of knowledge about the relationships of body states with observed properties, about the relationship of disease risks with their indicators, and about other clinical dependencies is formed as an information resource on the IACPaaS platform. IACPaaS technology is shown how to use it to develop knowledge base and explanatory solvers. The possibility of combining models and components for prognosis, risk assessment, etc. on the basis of a single ontology, makes it possible to comprehensively solve important problems in various fields of practical medicine, including assessing the patient's condition by "background" method. At the same time, the solver, integrated with the medical history and electronic medical record, refers to being updated and expanded knowledge bases and forms an explanation in terms understandable to the doctor.

TECHNOLOGY OF INNOVATIVE ENERGY DEVELOPMENT FORECASTING BASED ON INTELLIGENT DATA ANALYSIS

Kopaygorodsky Alex

Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia

Introduction. Unfortunately, scientific research and development cannot be carried out with the same efficiency in all directions at the same time. Investors want to invest resources and make profits from developments as efficiently as possible. This circumstance forces it to make decisions on planning and managing the innovative development of individual sectors of the economy [1, 2]. The development of information and telecommunication technologies has accelerated the transmission of knowledge and reduced the release time of new innovative market development. First, such an effect is observed due to the acceleration of the transfer of scientific knowledge and developing on their basis new production technologies with the subsequent release of products. In recent decades, there has been an active development of a whole range of intellectual approaches and methods for supporting decision-making on planning and managing innovative development of both individual sectors and the economy as a whole. In addition, recent years developed methods for determining new technological solutions based on intelligent semantic search technologies and Big Data [3, 4]. Tech Mining technique is used as a form of statistical contextual analysis of text documents based on scientific and technical resources to identify breakthrough technologies and developments, assess their innovative potential [5]. Forecasting methods for the development of the energy industry are not always effective in conditions of uncertainty and lack of the necessary information to test models, because they are based on mathematical models and software packages. To solve the set tasks, the authors propose to use intelligent methods of semantic analysis, machine learning and Big Data technologies to create tools that facilitate the work of expert groups, and tools that perform preliminary processing of information analyzed by experts. The sources of information can be Open Data and Big Data. The author applies to the analysis and classification of text information NLP approach [6]. Also, methods of semantic modelling can be effectively used for the "express analysis" of the collected information [7], the development of which is being carried out in the Department of Artificial Intelligence Systems in Energy of the Institute of Energy Systems named after L.A. Melentiev of the Siberian Branch of the Russian Academy of Sciences (ESI SB RAS).

Intelligent information system. Intelligent information system is used to support the activities of researchers in energy sector forecasting [8]. Developers apply a service-oriented approach in implementing an intelligent information system, which allows independent development of individual system components and provides overall flexibility. Figure 1 shows the architecture of the intelligent information system, which includes the semantic analysis of text data, ontological, cognitive and event modeling, the means of checking the hypotheses and visualizing the search results. The ontology system is an essential component of the repository. The ontology system consists of an ontology of energy industries and individual energy technologies, an ontology of energy research, an ontology of tasks, research methods, etc. This allows you to integrate knowledge and unify descriptions of analysis methods, formats, data used in them, specifications of software components that implement these methods.

Integrated warehouse contains not only documents of working research groups, but also a descriptions and references to external information resources that are linked with elements of the ontology system. Researchers receive new knowledge when processing search queries in external, with respect to integrated warehouse, software extractable data. New knowledge can be represented explicitly and uploaded into an integrated warehouse using collective work tools.

The presented architecture is open and allows you to connect new components for analyzing data placed in the repository.

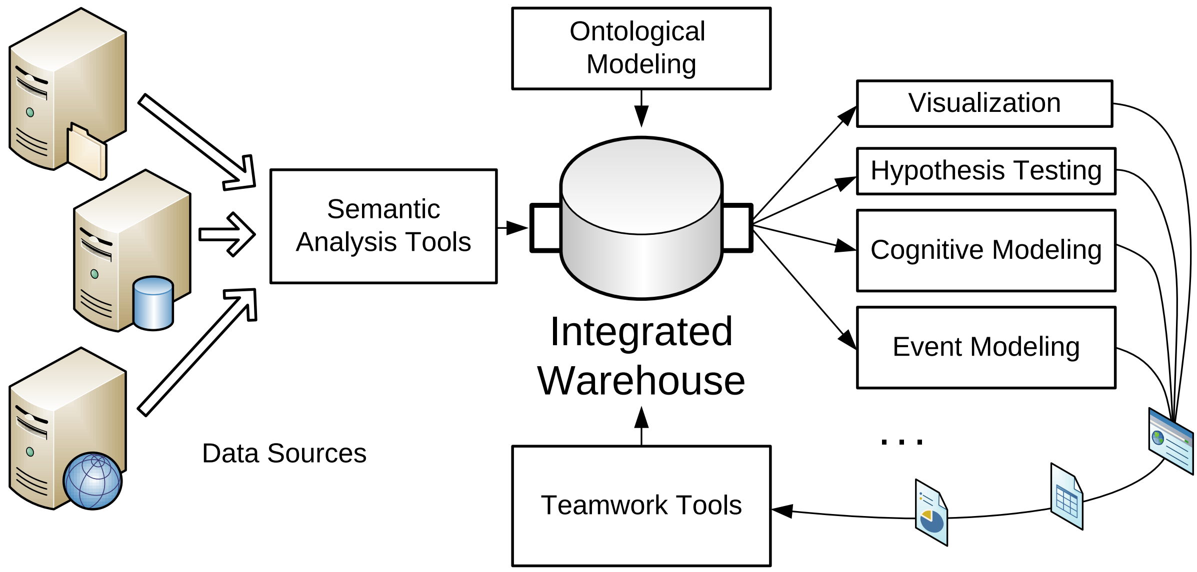

Figure 1. Architecture of Intelligent Information System.

Application for communication with external components of standardized interfaces and network protocols of the Internet, in particular JSON and HTTP, provides the integration of methods for solving non-trivial problems and allows you to access information and functional components located on remote servers.

Technology of forecasting. Since the analysis of incoming information requires a considerable time due to a large sources' volume, it was proposed to divide the process into two basic: (1) the process of information content of the repository and (2) the process of using the filled storage with researchers to solve applied tasks. The information content subsystem consists of search modules and analysis modules and classification. At the same time, one module of analysis and classification can serve several search modules, and several search modules can work in parallel with the information resources of the same class. The analysis module during the classification of text fragments is based on the data extracted from linguistic ontology, which defines the terminological specifics on scientific and technological solutions in the field of energy. The information content subsystem is a point of obtaining information (metadata, references to external resources and documents of researchers described in the concepts of linguistic ontology), which, after extracting, can be represented by the user or processed by other software agents. Many open data sources that aggregate information on scientific articles and developments support export to Research Information Systems (RIS).

The technology of building linguistic ontology includes four main stages, the first two of which are mandatory:

1. Building the source list of terms and keywords of the subject area.

2. Binding of sets of word-complexes with the concepts of ontology.

3. Formation of a list containing words complexes characterizing keywords compared with the basic concepts of ontology.

4. Translation of word-complexes characterizing keywords and basic concepts to a new language.

As a result of the implementation of the above actions, linguistic ontology will be formed, which allows the classification of text sources based on the occurrence of word-complexes.

On the basis of created ontology, you can perform the second step – the collection and classification of information, which is located in open sources. The collected information enters the integrated data warehouse. Subsequently, it is this related and classified information that can be used to build forecasts, analysis and visualization by other researchers and various instrumental means.

Conclusion. The implementation of an intelligent information system using a service-oriented approach and the integration of existing third-party and proprietary components will effectively solve scientific and practical problems associated both with the support of expert decisions on the strategic innovative development of the energy sector and in the field of scientific substantiation of strategic decisions on the digital transformation of the energy sector. The application of the proposed technology, methods and approaches provides a sufficient level of flexibility and extensibility. It will effectively solve problems in the field of scientific and technical forecasting of innovative energy sector development.

Acknowledgements. The author is grateful to the Russian Foundation for Basic Research (RFBR) for financial support. The reported study was funded by RFBR, project number 20-07-00994.

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ONTOLOGICAL AND COGNITIVE MODELING IN THE STUDY OF RESILIENCE OF SOCIO-ECOLOGICAL AND ENERGY SYSTEMS

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Currently, in the world scientific community there is an active development of the direction related to resilience research. The object of research in this direction are both technical systems and weakly formalized systems, such as social, environmental, etc. In the study of such weakly formalized systems, stability is distinguished, which in English is called "resilience".

Traditionally, in domestic studies, resilience was considered as the survivability of technical systems. However, recent trends in energy development, one of which is the trend towards a decrease in the carbon footprint of energy, require a joint consideration of both energy and socio-environmental factors. To assess the joint development of energy and ecological systems, it is proposed to use semantic technologies, namely ontologies and cognitive modeling.

In resilience studies, resilience assessment plays an important role. The tool for assessing resilience is an indicative analysis. Its implementation requires the development of assessment methods and the identification of resilience indicators. Studies of "elastic" sustainability involve a qualitative analysis, so it is required to develop a set of qualitative indicators and methods for assessing resilience based on the use of these indicators. It is proposed to use cognitive modeling to form resilience indicators. This requires studying the subject area and highlighting the necessary concepts. To form the concepts of the subject area, it is supposed to use ontological modeling technologies. Existing ontologies can be adapted or integrated with new ontologies, thus forming a common ontological space of the areas under study. On the basis of the ontological space, concepts are distinguished for the construction of cognitive models. To evaluate the indicators, a fuzzy scale is introduced, which is formed on the basis of expert assessments.

The proposed methods and tools of indicative analysis based on ontological and cognitive modeling technologies will make it possible to study the stability of such weakly formalized systems as socio-ecological systems together with energy systems.

Acknowledgements. The results were obtained with the partial financial support by RFBR grants № 20-07-00195.

RESEARCH OF INTERRELATIONS OF ENERGY AND SOCIO-ECOLOGICAL SYSTEMS USING SEMANTIC TECHNOLOGIES

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The relevance and necessity of studying the interrelations of energy and socio-ecologicalsystems is due to the importance of the problem of ensuring the sustainable development ofsociety as a whole and the sustainability of its technical and socio-ecological systems. The worksof foreign and Russian researchers are devoted to studies of the resilience of energy systems. They consider a methodology for quantifying the resilience of the energy system, and proposeindicators for taking into account the main criteria of resilience in social and technical systems. As a rule, such complex systems are described by numerous parameters and characteristics. Therefore, semantic technologies can be used to search, extract information and verify data. Ontological modeling, as one of the directions of semantic technologies, is used to describe and integrate knowledge of subject areas.

The impact of the functioning of energy facilities on the ecological state of the elements of the environment is studied. The work is carried out within the framework of the project supported by the Russian Foundation for Basic Research grant № 20-07-00195. These studies involve the integration of environmental and social components. Energy systems are critical objects of the country, as they ensure the functioning of the social infrastructure and all other sectors of the economy. And also energy systems are one of the serious objects of technogenic or anthropogenic impact on the environment and human habitat. Socio-ecological system is a complex interdisciplinary concept, the definition of which depends on the direction of research. According to the definition of Nobel laureate E. Ostrom, a socio-ecological system is an ecological system that is inextricably linked and dependent on one or more social systems.

The interrelations of energy and socio-ecological systems are expressed through the mutual influence of indicators of their functioning. Ensuring the needs of the population for electric and thermal energy reflects the relationship between energy and social systems. The state of the elements of the environment of the region (atmosphere, water bodies, soils, living organisms) reflects the relationship between the anthropogenic impact of the technogenic system and the quality of life of the population, taking into account natural and climatic conditions.

When analyzing the interrelations of energy production with the quality of life, it is necessary to single out, on the one hand, the anthropogenic impact of energy as a result of the entry of pollutants of various hazard classes into the elements of the environment and the human body. In this case, qualitative and quantitative characteristics of the anthropogenic impact of energy can become indicators of the quality of life. On the other hand, energy facilities provide the population with the necessary heat and electricity, which has a positive effect on the quality of life of the population.

An integral indicator of the quality of life, including objective and subjective assessments of various factors affecting a person’s life, can be used to reflect the interrelations and mutual influence of energy and socio-ecological systems and be one of the indicators of their sustainability.

As an example, this study considers the central ecological zone of the Baikal natural Territory, for which quantitative estimates of the morbidity of the population and emissions of pollutants into the atmosphere characteristic of energy facilities are shown. It is known that the quality of life of the population largely depends on the level of economic development (welfare) of the territory under consideration and, accordingly, economic indicators play a significant role in the development and management of socio-ecological systems.

To identify, describe and structure the interrelations of energy and socio-ecological systems, ontologies are developed that reflect these interrelations and a system of interconnected ontologies is proposed that ensures the integration of intersecting areas of knowledge.

Acknowledgements. The work is carried out within the framework of the project supported by the Russian Foundation for Basic Research grant № 20-07-00195 and the project on the state task of MESI SB RAS, State registration №.FWE U-2021-0007.

MATHEMATICAL MODELING OF PLASMA FLOW AT LOW PRESSURES IN VACUUM CHAMBER WITH CHARGE ON BODY

Shemakhin Aleksandr[1], Zheltukhin Victor[1,2], Shemakhin Evgeny[1]

[1]Kazan Federal University, Kazan, Russia
[2]Kazan National Research Technological University, Kazan, Russia

RF plasma at low pressures (p= 13.3−133 Pa) with gas flow is effectively used for modifying the surfaces of materials of organic and inorganic nature [1]. This type of plasma has the following properties: degree of ionization - 10^{-4}–10^{-7}, electron density - 10^{15}–10^{19} m^{−3},the electron temperature - 1−4 eV, the temperature of the atoms and ions in the bunch $(3-4)\times10^3$ K in the plasma jet $(3.2-10)\times10^2$ K. The main feature of RF plasma flow at low pressure is in flow regimes that for neutral component plasma flows in a transitional mode between the continuum mode and free-molecule flow, the charged components can be approximated of continuous medium [2-4]. Calculations of the RF plasma flow with charge on body in vacuum chamber are completed. On body was set a third-type boundary conditions for electrons. The distributions of the velocity modulus, pressure and temperature of the carrier gas argon and the electron density, electron temperature, potential and tension of curl electric field are obtained.

Acknowledgements. The reported study was funded by Russian Science Foundation, according to the research project No. 19-71-10055.

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STUDY OF THE OPERATION OF A SELF-TUNING PREDICTIVE SPEED CONTROLLER OF A SYNCHRONOUS GENERATOR ON A CYBER-PHYSICAL MODEL

Bulatov Yury[1], Kryukov Andrey[2,3], Suslov Konstantin[3]

[1] *Bratsk State University, Bratsk, Russia*
[2] *Irkutsk State Transport University, Irkutsk, Russia*
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In the context of the deep integration of computing resources into physical processes with the view to controlling electric power systems, the creation of cyber-physical power systems (CPPSs) comes to the fore [1, 2]. The CPPS concept implies fast and reliable integration of various distributed generation (DG) plants [3-5], which requires tuning their controllers.

DG plants based on synchronous generators with automatic voltage regulators and rotor speed regulators have become widespread. Since there can be various disturbances in the CPPSs, the optimal settings of the controllers are necessary for all possible operating conditions of the DG plants. On the other hand, it is possible to use controllers with a linear predictive link [6] and, as studies show [7, 8], use typical settings for all possible operating conditions of the DG plant.

The paper describes a self-tuning predictive rotor speed controller of a synchronous generator, whose operation is based on determining the time constant of a linear predictive link for the resonant frequency of the rotor self-oscillations. When the synchronous generator load angle δ changes, the proposed controller automatically calculates and changes the forecast time. The paper also presents a computer model of the proposed self-tuning predictive controller, which is made in the Simulink package of the MatLab system. The performance of the self-tuning predictive controller is compared with that of a typical proportional-integral-derivative (PID) controller in various operating conditions of the DG plant. The studies employ a cyber-physical model of a turbine generator set under the control of the Real-Time Windows Target package of the MatLab system.

The findings of the experiments have indicated the advantages of the self-tuning predictive speed controller and demonstrated its performance compared to a typical PID controller in all considered operating conditions without its tuning.

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THE USE OF DIGITAL TECHNOLOGY IN BUILDINGS IS A WAY TO DECARBONIZE THE ENERGY SECTOR

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According to the data presented in the International Energy Agency's "2021 Global status report for buildings and construction" [1], the construction and maintenance of buildings accounted for 37% of global greenhouse gas emissions in 2020. The largest contributor (49% of the total amount) is electricity production for use in buildings, 23% is produced by burning fossil fuels (such as natural gas burned for heating, hot water production, and cooking), and 28% of greenhouse gases are produced in the process of manufacturing of construction materials such as steel, concrete, and glass. Reducing carbon emissions from this sector will be critical to meeting the Paris climate agreement's goals[2] and achieving zero emissions by 2050.

Decarbonization requirements encourage the use of advanced technologies as regards heat insulation, heating, and air conditioning of buildings [2]. Thanks to the increasing digitalization of the maintenance of buildings, their energy efficiency has improved significantly. Digital solutions perform three basic functions: (1) monitoring energy consumption (e.g., with 'smart meters'); (2) identifying potential energy savings; and (3) reducing energy consumption through intelligent control. Digital technology can reduce energy consumption in some types of buildings by almost 20%. The use of motion, light, and temperature sensors, together with algorithms of predictive behavior of consumers reduces heat and electricity consumption in buildings and allows maintenance organizations to monitor the technical condition of energy supply systems.

Moreover, the power grid, to which the buildings are connected, is also changing and becoming more and more intelligent. The digitalization of the energy industry and buildings improves the control of equipment, machinery, and software, allowing buildings to "see" what is going on inside and interact in a new way with the energy systems to which they are connected [3]. There is already a new type of buildings: a building that interacts with the grid (Grid-Interactive Building). As part of the interaction between smart buildings and smart grids (concept Grid Edge), buildings can play an active role in decarbonizing the energy system [4].

In Russia has adopted a number of documents[3,4] to achieve carbon neutrality by 2060. The Strategy for Socio-Economic Development of the Russian Federation with Low Greenhouse Gas Emissions to 2050, among other measures, envisions the implementation of measures in construction and the housing and public utilities sector. These are: "setting more stringent requirements for energy efficiency of new residential, public and industrial buildings, energy-efficient modernization of existing buildings heated by district heating or individual heating, hot water and heating systems, replacement of household electronic appliances and lighting systems with energy-efficient ones, etc.".

An earlier research contribution by the author [5] showed that given the adoption of global trends with respect to the diffusion of digital technology in the Russian housing sector in 2030-2050 the greatest reduction can be expected in the consumption of heat, that of about 360 million Gcal (52%). Taking into account the mix of fuels used for thermal energy production in Russia [6] and coefficients of CO_2 emissions from fossil fuel combustion [7] it can be assumed that such

[2]The Paris Agreement is a legally binding international treaty on climate change. Adopted by 196 Parties at the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change on December 12, 2015, in Paris. Entered into force on November 4, 2016.
[3] Federal Law No. 296-FZ of July 2, 2021, on Limiting Greenhouse Gas Emissions.
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a reduction in heat consumption will reduce CO_2 emissions in the energy sector by at least 75 million tons.

The world's energy transition is related to digitalization, which covers a wide range of issues: from the collection of detailed digital information online to data processing, to the optimization of energy production, transmission, and consumption. The application of Building Information Modeling (BIM) technologies, smart home technologies, including Internet of Things (IoT) technologies, Big Data processing technologies, smart engineering equipment control systems based on optimization solutions, high-tech energy-efficient equipment, innovative materials, non-conventional renewable energy sources (NRES) [2] will reduce the required amount of energy consumption during construction and maintenance of buildings and will contribute to the decarbonization of energy.

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TWO-LEVEL TECHNOLOGY FOR STUDYING ENERGY SECURITY THREATS USING COGNITIVE MODELING METHODS AND LINEAR OPTIMIZATION MODELS

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Modern conditions for the development of information technologies, the emergence of high-performance computing tools, as well as the intellectualization of energy systems and the need for their functioning in a digital economy, on the one hand, impose special requirements on the model-ing and computing tools used. On the other hand, they provide opportunities to improve the adequa-cy and correctness of modeling real systems, to take into account the inertia of processes, the dy-namics of the emergency situations development in the fuel and energy complex, non-linearity in terms adequacy of the representing processes in energy systems to improve the accuracy of deci-sions.

Due to the impossibility of conducting full-scale experiments on working energy systems of the fuel and energy complex, studies related to modeling these systems, developing specialized software and tools, rational organization of a computational experiment to find ways to provide consumers with energy resources without a deficit when functioning under normal conditions and conditions of emergency situations.

This work is an integral part of the energy security research carried out at the Energy Securi-ty Department of the Melentiev Energy Systems Institute (ESI) of the SB RAS [1-4].. Similar stud-ies and models for such studies are mainly focused on solving the problems of long-term planning of the power industry work under normal operating conditions with a horizon of up to 15-20 years. Similar works carried out in other teams are of a local or regional nature with the study of certain aspects [5-10]. Comprehensive studies that allow assessing the possibilities of all energy sectors interconnected work and determining the consequences for consumers of energy resources in the event of emergency situations in the operation of one industry or several industries at the same time have not been carried out before.

The studies carried out in the Department of Energy Security of the ESI SB RAS are distin-guished by their focus on solving the problems of assessing the behavior of energy systems in the face of energy security threats, optimizing the modes of the energy systems interconnected opera-tion in emergency situations for reliable energy supply to consumers. Based on the results of the studies, it is proposed to form a certain list of measures to ensure the level of energy security at the appropriate level.

To conduct research on assessing the impact of energy security threats on the reliability of energy supply to consumers in emergency (critical) situations, the ESI SB RAS proposes to use a two-level technology that integrates the stages of qualitative analysis (using semantic modeling tools) and quantitative analysis (using linear economic and mathematical models and traditional software systems) [11]. To conduct a comprehensive experiment to analyze the main threat to ener-gy security "Lack of investment in the energy sector", it is planned to jointly use cognitive models of energy systems (gas, coal, electric power) and a model for optimizing options of the fuel and energy complex development, taking into account energy security factors.

For the first stage of the qualitative level, a cognitive threat model "Lack of investment" for the gas industry was formed.

At the second (quantitative level), it is proposed to use an economic-mathematical model to optimize options for the development of the fuel and energy complex, taking into account energy security, described in [1-4]. The model combines blocks simulating sectoral subsystems of the en-ergy complex (gas, coal, oil refining industries, electricity and heat).

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DEVELOPMENT OF MODELS FOR ANALYZING THREATS TO THE INDUSTRIAL INTERNET OF THINGS IN THE ENERGY SECTOR

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Energy facilities are considered as cyber-physical systems in connection with the concept of digital transformation of energy. The transformation of energy systems into cyber-physical energy systems has become possible primarily due to the high-growth developing of efficiency of information and communication technologies, remote measurements, wireless sensor networks and the industrial Internet of Things [1, 2]. The report examines the vectors of cyber threats to the Internet of Things at an energy facility. Cyber threat vectors are part of threat modeling approaches. The report examines the previously proposed approaches to threat modeling as regards to study the vectors of cyber threats to the industrial Internet of Things. ATT & CK approach of MITRE allows ones to analyze tactics and possible techniques for carrying out targeted attacks. The Cyber Kill Chain approach [4] describes a cyberattack lifecycle model, and later the adapted Cyber Kill Chain ICS model for automated control systems (ACS) identifies three categories of common methods for achieving functional impact on ACS: loss, failure and manipulation [4]. The STRIDE approach by Microsoft includes six types of threats, matching of the first letters of which constitute the abbreviation of the approach: Spoofing, Tampering, Repudiation, Information disclosure, Denial of Services, Elevation of Privilege [5].

The report presents the development of the knowledge base and the construction of semantic models based on the above conceptual approaches to threat modeling in the aspect of vectors to the industrial Internet of Things of energy facilities.

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ANALYSIS OF APPROACHES TO MEDIUM-TERM FORECASTING OF EARTHQUAKES BASED ON FUZZY LOGIC METHODS

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Earthquakes, while being the most relevant out of the natural hazards characteristic of the Baikal region, are also the least predictable as far as preventively determining the place (longitude, latitude, and epicenter depth), time, and intensity are concerned, because it is reliant on processing an existing catalogue of seismic events with the purpose of making out the patterns via the analysis of the so-called earthquake precursors – such factors as the existence of the seismic «stain» (a concentration of epicenters), the alterations in the number of earthquakes and energy output over time, and others. Despite the existence of the methodological approach to mid- (3 months – a year) and long-term (years) earthquake forecasting, none of the aforementioned precursors are considered mandatory and conclusive, and no combination of them gives a complete guarantee of a seismic event actually occurring. Moreover, obtaining the precise location of the epicenter and the time of an event is impossible due to the little existing knowledge of the nature of seismic processes, therefore the analysis produces ranges within which these values fall.

The process of forecasting itself is performed by an expert based on a dataset of some kind. In regards to the Baikal Rift Zone (BRZ), the analytical processing is done at the Crust Institute using the output of the «Prediction» software developed there, which uses the contents of the database containing a formatted (time-coordinates-intensity) catalogue of earthquakes, the list of topographical and geological objects, and the catalogue of expected earthquake locations based on previous prognoses. «Prediction» implements the models for defining seismically active regions, intensity decay related to the epicenter, energy output, and provides a toolset for building diagrams depicting the time-based changes in earthquake amount, energy release, earthquake repeatability.

Although the software provides the expert with the data necessary for the final stage of the analysis, the lack of formalized approach which would allow to calculate the time, the intensity, and the location of a potential earthquake via a program without the expert's input, combined with the low quality of the monitoring network (and also the lack of catalogue uniformity due to the development of the monitoring station network over time) demands the creation of a new approach, which either solves those issues or takes them into account. It is most rational to based such an approach on the fuzzy logic methods and the use of fuzzy sets, where belonging to a set is defined not as a binary 0 (belongs) / 1 (doesn't belong), but rather through a membership function which can take any real number ranging from 0 to 1 as a value, determining the degree of membership. That allows to account for the imperfection and / or inaccuracy of data or knowledge, and an approximate or an incomplete state of the input, using qualitative assessments in place of mathematical calculations – which allows to simulate the work of an expert, transforming knowledge and experience into fuzzy logic rules. The fuzzy logic rules are a set of «if-then» expressions containing linguistic expressions, numeric variables and constants. Using them to define the degree of membership, it is possible to obtain an output of statements which by themselves carry a degree of uncertainty (e.g, «if there exists a period of inactivity with the length m – n after an earthquake, accumulation of seismic energy increases, which raises the risk of occurrence of a new earthquake within the seismically active area»).

The usage of fuzzy logic methods is described in most detail in the sources [1] и [2], where the fuzzy-based forecasting of earthquakes is applied to the seismically active areas of the Tiangxiag plateau (Pakistan) and the Zagros belt (Iran) respectively. In both cases the fuzzy-based rule system contains the following:

1. A dataset containing input feature vectors along with their labels. Using this dataset, we can define the domain margins for each feature and divide each domain into equal intervals with overlap. For each interval, a membership function is assigned and, therefore, each input pattern can have a degree of belongingness to more than one membership function. Each of these functions takes a linguistic label for expressing the antecedents of the fuzzy rules.

2. A fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values. In other words, when input vectors are passed through these membership functions, the belongingness of inputs to each membership function is separately determined. In other words, input values are converted into so-called fuzzy numbers.

3. A rule-base engine containing a number of fuzzy ‘‘If– Then’’ rules, which are the interpretable linguistic rules. The main fuzzy process, prediction rules, is occurred at this stage.

4. A decision-making unit that is an operator to determine the output of each rule (consequence) according to the combination of input fuzzy values (antecedents). This operator can be Min, Max, AND or a weighted average of input membership values.

5. A defuzzification inference which transforms the fuzzy results of the inference into crisp output. In other words, results of fuzzy rules are fused in this stage to map the human-like decision making into environment.

The difference between the works lies in the rulesets and conditions which are based on the differences between the researched regions, therefore with the Baikal rift zone it will be necessary to develop a unique ruleset in order to implement an expert system based on the fuzzy logic methods using the existing methods of calculation used by the expert for manual forecasting.

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PREVENTIVE ANALYTICS IN SAFETY TASKS FOR CRITICAL INFRASTRUCTURES DEVELOPMENT

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An intelligent information technology for situational modeling of industrial-natural complexes (INCs) of various scales for the purpose of strategic and operational management of them, oriented towards unified processing of heterogeneous information regarding static and dynamic characteristics of such systems, is considered. The urgency of the task is caused by: current complication and interpenetration of INCs; growth of uncertainties in the world due to accelerating development of the INCs; increasing data availability resulted from the advent of the Internet of Things (IoT).

The novelty of the proposed approach lies in integration of tools for studying poorly formalized complex non-stationary spatial objects within the framework of cause-and-effect models as well as in integrated usage of expert knowledge to form criteria and select preferable options for implementing INCs structures, which are studied in more detail in a simulation mode with using digital twins of INCs components.

The strategic modeling of INCs is aimed at analysing the structure of potentially hazardous facilities being designed and their interconnections to identify possibilities of dependent (complex, cascading) failures (DCCFs), which generate chains of events that yield most significant damage in emergencies and critical situations. This mode solves the problem of preventive analytics for finding and scenario forecasting of “bottlenecks” in the structure of an INC with possibilities to assessing damages from DCCFs and substantiating rational measures to prevent them. *To improve safety, it is advisable to embed models of new devices and systems in the virtual world before incorporating them in the real world.*

For operative modelling of INCs, quantitative estimates of situational awareness (SA) of the decision makers involved in INCs functioning are proposed by means of metrification the space of all three main aspects of the SA, which makes it possible to objectify assessing the achieved degree of the SA and is especially important when various components of one INC are within the responsibility of several decision makers. For this case, the proposed approach allows coordinating actions of decision makers and preventing conflicts between them.

INCs are considered as hierarchical systems; with the growth of their scale, a transition to a network-centric model is possible; then areas of responsibility of decision makers are formed dynamically based on results of assessing their SA.

Distributed implementation of the proposed technology makes it possible to solve the issues of copyrights and secrecy in development and application of local submodels of INCs components by analogy with GRID technologies. Developers of new INCs components will be able to justify the safety of including their object in critical infrastructures, taking into account its relationship with other components already specified in the modelling system. Such an analysis can become an important aspect in increasing objectivity of feasibility studies of supposed structural solutions and seems essential in the modern style of digitalization of the Russian economics.

MATHEMATICAL MODELING OF DIFFERENT ASPECTS OF AGRICULTURAL PRODUCTION UNDER CLIMATIC AND BIOLOGICAL RISKS

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To solve practical problems related to the production of agricultural products and the harvesting of food wild resources, mathematical programming problems with uncertain coefficients are used with unknown variables of the objective function and constraints. In this case, the right-hand sides of the conditions of the extremal problem can change to a large extent.

A strong influence on the production and economic indicators of mathematical models is exerted by extreme hydrometeorological and biological phenomena, the consequences of which are losses in the receipt of products by commodity producers.

Hydrometeorological events, which include showers, early snowfalls, droughts, frosts, rain floods and spring floods, as well as their combinations, have features of variability. For their description, methods of mathematical statistics and probability theory are used. The rich empirical material and the identification on its basis of patterns of long-term series of climatic indicators show the applicability of the probability distribution laws for complete sequences, truncated samples, sequences with zero values and rare events.

Somewhat less damage to agriculture is caused by biological phenomena that reduce profits from the production of crop and livestock products. In the first case, economic losses are associated with the invasion of locusts, the number of rodents, pests of agricultural plants. In the second case, the livestock sector receives less products due to epidemics, contagious and non-contagious animal diseases. Studies show that in some cases it is possible to detect significant trends in biological indicators, and in others it is better to use statistical methods of evaluation.

The obtained patterns of variability of hydrometeorological and biological indicators suggest the use of extreme tasks for modeling the production of agricultural products, which differ in industry characteristics, features of dynamics and probabilistic patterns of variability of coefficients and right-hand sides of the restrictions. At the same time, the developed models for optimizing the production of agricultural products are focused on describing the situations of the activity of an agricultural producer in different conditions: averaged, unfavorable and favorable.

MODELS OF MANAGEMENT OF AGRICULTURAL PRODUCTION ON LANDS WITH DIFFERENT FERTILITY

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Agricultural producers of different categories (organizations, peasant (farmer) farms) carry out production on heterogeneous agricultural lands, which differ in relief, slope exposure, soil characteristics, microclimatic conditions.

This specificity of the state of agricultural land can be assessed using various sensors that determine the mechanical, chemical composition of the soil and its moisture content during the growing season. As additional information, satellite images are used, as well as the results of monitoring the earth's surface using unmanned aerial vehicles. The assessment of the fertile potential of the soil, the natural and climatic features of the economy and production technologies, as well as the use of mathematical modeling methods contribute to the effective planning of agricultural production.

To solve this problem, it is proposed to use linear programming models in the conditions of heterogeneity of land resources. It is obvious that the main indicator characterizing different conditions for the growth of agricultural crops is the yield, which varies greatly depending on the size of the farm area. For large farms with an area of tens of thousands of hectares, the discrepancies in crop yields for different areas are usually higher than for small plots with sizes corresponding to hundreds and thousands of similar dimensions.

When optimizing the production of agricultural products on heterogeneous lands, various options for applied models are offered: linear, parametric, stochastic. At the same time, two groups of tasks are considered that describe the activities of agricultural producers. Models of the first group describe the production of products in some average climatic conditions, and other models take into account the impact of extreme climatic events on the economy.

The developed mathematical models are tested on real agricultural objects of the Irkutsk region. The advantage of such models is a more detailed description of the process of obtaining agricultural products, identifying discrepancies between sites in terms of the potential for obtaining products, and the ability to determine the best options for the distribution of crops. In addition, the proposed models contribute to improving the efficiency of planning production processes.

For models of optimization of agricultural production, profit, environmental damage, labor costs, and others can be used as an objective function. As constraints, resources are used to obtain products in specific heterogeneous areas.

DATA MONITORING FOR INFORMATION SYSTEM FOR VISUALIZATION FORECASTING AND PLANNING ACTIVITIES OF AGRICULTURAL PRODUCER

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Digital technologies cover various areas of human activity, including agriculture. Huge crop areas, a variety of natural and climatic conditions even in one farm, not to mention significant territorial heterogeneity, new technologies for the production of agricultural products, the use of modern complexes, the rapid development of crop and animal breeding at the genetic level require the introduction and development of digital technologies.

Monitoring data at each stage of the process of obtaining agricultural products (soil preparation, sowing, plant care, harvesting) allows you to create a database for the accumulation and processing of information for the purpose of operational decisions, forecasting and planning with different lead times. In addition, to detail information support, it is necessary to use expert assessments, the opinion of agronomists on crop production and veterinarians, and zooengineers on the prevention and treatment of animals and technologies for the production of livestock products.

When solving the monitoring problem, it is of great importance to determine the number of operations that reflect the stages of the technology for obtaining agricultural products, and the choice of sensors that record the state of the process for some time.

Monitoring the process of performing field work requires the use of additional information regarding the impact of extreme events on crops, and, ultimately, on crop yields. Unfavorable conditions may arise as a result of the formation of hydrometeorological, biological and technogenic events. Tracking the spread of extreme events in space can be assessed using satellite images as an addition to ground-based information, including data from the hydrometeorological service.

The creation of an information system with a database, as well as the developed mathematical and algorithmic support, allows solving the problems of operational changes in the technologies for obtaining products, predicting and planning various aspects of the activity of an agricultural producer.

The main sectors of monitoring the receipt of agricultural products for management include crop production, animal husbandry and their combination.

INFORMATION AND COMPUTING SYSTEM FOR ENERGY OBJECTS IMPACT ASSESSMENT ON ENVIRONMENT

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Currently, the issues of assessing the impact of energy facilities on the environment are attracting more and more attention in the world. In the Russian Federation, reducing the impact of energy facilities is envisaged in the Energy Policy of the Russian Federation until 2035 [1], the national project "Ecology" [2], as well as the Strategy for the socio-economic development of the Russian Federation with low greenhouse gas emissions until 2050 [3]. However, the evaluation process can be difficult because such studies are complex, require significant amounts of data both on the objects themselves and various supporting information. Thus, to substantiate and support decision-making to reduce the harmful effects of energy facilities on the environment, it seems appropriate to involve intelligent information and computing systems.

The report discusses the information and computing system (ICS) WICS for assessing the impact of energy facilities on the environment. ICS integrates subsystems for performing calculations, visualization tools for results, a knowledge base, and a database, as well as service components for working with external information sources. Also, a technology for assessing the impact of energy facilities on the environment and supporting decision-making to reduce their harmful effects is presented. It is based on the author's methodic approach [4] and ICS WICS. The results of approbation of the technology and ICS, obtained as a result of computational experiments, are shown.

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ELEMENTS OF MATHEMATICAL SUPPORT IN MODELLING SITUATIONAL AWARENESS

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The problem of developing a taxonomy of situational awareness (SA) [2] is considered. For mathematical support of the description of control [2] and SA-problems, it is proposed to refer to the mathematical foundations of modelling physical (mechanical, engineering, etc.) processes occurring in real time. When searching for the necessary information about modelling, it is suggested to use a semantic approach using machine learning (ML) metrics [3]. The purpose of modelling is to determine the situation and the parameters that can be influenced, that is, to make the situation controllable.

A deep knowledge of mathematics in the 21st century is the lot of specialists. This is due to the emergence of numerous information applications that allow a modern person not to refer directly to mathematical knowledge, but to use its applied results. Against this background, it is forgotten that the digital world that modern cybernetics has given us is completely based on the mathematical representation of knowledge about all phenomena and objects of being. The founders of the theory of automatic computation and the concept of creating cellular automata, Alan Turing [4] and Von Neumann [5], were outstanding mathematicians. Von Neumann, an expert in shock wave modelling, became in his time a leading specialist in "heavy" computational algorithms. He also owns the modelling section, which is now referred to as "game theory" and is a necessary part of situational management models. Norbert Wiener [6], who introduced the use of the term “cybernetics” as the science of control and information transmission, was a specialist in mathematical logic, probability theory, integral calculus and many engineering sciences.

Mathematical modelling is a necessary component in the theory of control [7] and decision-making theory. All tasks related to situational management are based on certain models of what is happening, and these models are based on some mathematical abstraction. The level of abstraction in the decision-making process mostly depends on situational awareness, that is, the informational picture of events and the competence of the performers. To take into account subjective and objective circumstances in management, it is necessary to form a description of the structure of what is happening on the basis of cause-and-effect relationships, that is, to set the task of developing for a SA-taxonomy. When forming this taxonomy, it is necessary to take into account the connections that are described using the equations of mathematical physics, since they underlie the modelling of physical, technical, social and many other processes that involve the objects of a critical situation. The modern approach to modelling is also implemented on the basis of the semantic approach [8] to information retrieval using artificial intelligence algorithms and ML metrics. The semantic library LibMeta is used as a terminology base [9].

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THE DIGITAL TWIN OF THE DEMAND RESPONSE AGGREGATOR

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In 2019 the Pilot Project of the SO UES Aggregator of Electricity Demand Response (DR-Aggregator) has been launched in Russia [1]. In foreign countries, the DR Aggregator was created to purchase excess electricity from owners of a large number of renewable energy sources. In Russia, the DR-Aggregator mechanism allows to reduce peak loads by shifting the consumption schedule of active consumers (AC) that are not part of the wholesale market.

Considering that the activity of the DR-Aggregator covers the territory of the whole country, for greater management flexibility in [2], a cluster structure is proposed for the DR-Aggregator, in which active consumers are united geographically. Such a structure can become typical for the operational interaction of Aggregators-clusters with the center (DR-Aggregator).

For greater efficiency in the interaction of active consumers within clusters in [3], a network-centric management system (NCM) is proposed. In the structure under NCM, the interrelationships of objects within each level are considered. For the DR Aggregator, the NCM regulates the acceptance by one active consumer of obligations to reduce the load of another active consumer (in the event of an accident at the latter's facility).

Modern power facilities are equipped with computer networks in addition to electrical and power equipment. The division of the AP functionality into cyber and technological subsystems makes it possible to represent the AC in the form of a cyber-physical system (CPS) [4], taking into account the cyber and technological subsystems influence each other.

Also, taking into account that together the CPS and the NCM create the basis for cyber-physical management (CPM) [5], next we consider the structure of the DR-Aggregator under CPM [6]. This means that at the lowest level of the DR Aggregator hierarchy (technological), adaptive control loops can be created that allow predicting possible technical failures, changing the control logic if these failures occur. The appearance of these control loops makes it possible to increase the cybersecurity and stability of active consumers.

In [7], the DR-Aggregator is considered as a business process for understanding the formulation of the task, the form of management, the resources used, for taking into account force majeure and obtaining the result of the functioning of the DR Aggregator.

In this report, we set the task of creating a digital twin [8] of the DR-Aggregator, taking the cluster structure and the cyber-physical management model as a basis for it.

The purpose of creating a digital twin of the DR-Aggregator

The DR-Aggregator is a complex infrastructure, it can be considered as a large enterprise with branches (or as an organization). The digital twin (DT) of an organization is a model that describes as accurately as possible the real cause-and-effect relationships between production, economic, financial and organizational indicators. Tasks when creating a digital twin of the organization are: support for making optimal management decisions at the stages of planning, monitoring and analysis of both the organization as a whole and individual areas of activity (functional blocks, programs/projects, assets, etc.).

Distinctive features of the organization's DT [9]:

Orientation to the vision of the future - the application of the digital model of the organization is aimed at forecasting its future and its environment, as well as supporting the adoption of optimal management decisions;

Universality - knowledge from all functional areas is described on the basis of uniform principles, which makes it possible to combine them into a single model;

Systematization – the knowledge of all participants forms a single system of interrelated indicators. The change in the indicator in any part of the model will be tracked and evaluated throughout the chain of cause-and-effect relationships;

Socialization - the knowledge of the model is available to the maximum number of employees and is the object of communication, expertise and collaboration;

Continuous evolution - the model is constantly changing, as algorithms are updated based on the results of plan-fact analysis and expertise, new knowledge can be introduced into the model at any time.

Taking into account the above, the Digital Twin of the DR-Aggregator can be represented:

Orientation to the vision of the future - the development of the mechanism of the DR Aggregator from the stage of the Pilot project to the stage of automatic connection of the AC to the nearest Aggregator–cluster.

Universality is a single model based on the same principles of describing functional areas (Common Information Model, CIM), since all active consumers are objects of the electric power industry.

Systematization is the construction of a NCM within Aggregator–clusters, which leads to the fact that the change in the indicator in any part of the model will be tracked and evaluated along the entire chain of cause-and-effect relationships. Also, the NCM becomes the key to Socialization.

Continuous evolution - the model of the DR-Aggregator from the Pilot Project stage to the automatic operation stage will constantly change, and the algorithms will be updated as new equipment develops during the operation of the CPM.

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INTEGRATION OF COGNITIVE AND MATHEMATICAL MODELING BASED ON ONTOLOGIES IN SOFTWARE INTEC-A

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The MESI SB RAS actively conducts predictive studies of the fuel and energy complex from the standpoint of energy security [1]. To conduct these studies, a model of the fuel and energy complex was developed that describes the production, storage, transport and consumption of fuel and energy resources (FER) by region [2]. In the mathematical sense, the classical problem of linear programming is solved with the help of the model.

Forecast studies of the fuel and energy complex are of a multivariate nature, and the multivariance increases significantly due to the need to take into account energy security requirements: scenarios of possible emergency situations (ES), as well as preventive (preventing the occurrence of emergencies), operational (performed during emergencies) and liquidation scenarios are superimposed on the basic options. (eliminating the consequences of emergencies) measures [3]. To automate this study, a software package (SP) "INTEC-A" was developed.

The use of cognitive maps in relation to the problem of energy security makes it possible to form scenarios for sustainable and crisis development of the energy sector in the region, to identify factors influencing scenarios for the development of the energy system, and to develop plans to counter threats to energy security.

It is proposed to integrate the support of cognitive modeling in the SP "INTEC-A", to provide the possibility of forming and correcting the computational scenario. This also requires integrating ontologies and using them as an auxiliary tool for cognitive modeling, in other words, as classifiers of concepts that are used in the construction of cognitive maps.

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DEVELOPMENT OF THE DIGITAL TWIN OF WIND POWER STATION: PROBLEM STATEMENT

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The notable history of digital twins (DT) dates back to the 1970s when the Apollo 13 incident occurred. The DT's capabilities helped to find the only possible way to save the crew and successfully land the spacecraft. At present, DT remains one of the most promising technologies, according to research by Gartner [1].

The report discusses the history of forming the term "digital twin". A review of the existing solutions for the use of DT in wind energy is carried out. In addition to this, the research task is set (digital twin development of a wind power plant (DT WPP)) and the initial steps in designing a prototype of a DT WPP. Finally, the evolution of the term DT will be considered in the framework of M. Grieves and J. Vickers [2, 3].

According to GE Renewable, the DT increases the power generation efficiency of a GE wind turbine in the range of 5% to 7% [4]. From the previous, we can conclude that DT WPP is a hot topic. However, it is challenging to implement simultaneously due to the lack of a methodology for designing and building such systems. In turn, our study aims to construct a methodology for the development of DT WPP for standardization and reducing the cost of developing new solutions in this area.

The report discusses the approach to the construction of the DT based on ontological engineering. A fragment of the system of ontologies of wind systems necessary for constructing a digital shadow is given. The applied mathematical model for determining the operating parameters of a wind power plant is considered. Attention is paid to the design of the architecture of the DT, which consists of a digital shadow, a digital model, and a control system. The report draws attention to designing the structure of interaction between the DT and the SCADA system. Also, the tasks assigned to the SCADA system in the architecture of the DT WPP are determined. The report ends with plans for further development of the system and summing up the work results.

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WEATHER FORECAST USING LSTM MODEL

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The paper considers the prediction of time series using LSTM networks. As an example, the time series of weather characteristics for 106,000 hours is analyzed.

The use of recurrent neural networks allows you to "train" the model using several iterations, which leads to a reduction in modeling errors. The information in the neuron entering the input can be remembered. It follows that the use of recurrent networks when predicting time series is the best choice. For the task of forecasting weather data with short-term and long-term trends, long-term short-term memory (LSTM) is used.

The feature of the architecture of LSTM networks is the use of "memory blocks", and the main control mechanism is "gates". Neural network training takes place in three stages. At the first stage, the information that should be removed from the block is determined. At the second stage, the selection and saving of new information for updating the state. At the third stage, the output values from the "memory block" are calculated based on the information received.

Two types of data are used in the construction of the model: time and solar radiation. Based on the results obtained, it can be concluded that the constructed network takes into account short–term trends - the time of day, as well as long-term trends - the time of year. There is a problem taking into account peak values, the network outputs the maximum value: 800, and the actual value: 976. It is possible to assume that the network can be adjusted based on actual values and thereby improve its work.

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DATA IMPUTATION AND TIME SERIES FORECASTING FOR THE DIGITAL TWIN OF A SOLAR POWER PLANT

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There are two stages in the development of digital twins: the development of a prototype using the scientific tools of researchers, and the debugging of information interactions with real information flows to solve specific problems. Working with real data is allowed only at the second stage, therefore, it becomes necessary to create a generator of plausible synthetic data, which could later be used during testing of the digital twin already at the first stage. As the first prototype, at the Institute of Energy Systems. L.A. Melentiev SB RAS, it was decided to develop a model for generating and imputing data for the digital twin of a solar power plant, based on the available weather data received from a real object.

Nowadays, solar energy plays a big role in electricity generation as renewable energy sources become a promising alternative for the world at large. However, the disadvantage of renewable sources is intermittent availability, which negatively affects energy management. In order to offset this kind of instability, solar irradiance must be predicted to better represent the potential amount of electricity for a given solar panel system. Several forecasting models already exist for predicting future radiation, including those that incorporate artificial intelligence technologies such as the Numerical Weather Prediction (NWP) model, which is explained as non-linear PDEs of weather variables, using time series as a time fix radiation. This technology may be implemented in the future, when there will be a need to generate values in a complex, with the subsequent calculation of the amount of power depending not only on solar radiation, but also on humidity, wind speed, etc. The priority of the first prototype will be more focused on the imputation of missing data. [1]

Parameter estimation in a time series model definitely requires a complete set of historical data. The data often contains missing values. Moreover, the absence of data usually lasts for several days in a row. In this case, you could handle it differently by filling in the value of the records from other sensors, however, there is no guarantee that the spare sensors will also not fail. More advanced methods of multiple imputation, such as Principal Component Analysis, are implemented in MATLAB as a toolbox. However, such methods usually assume that the data are static random variables and do not use the temporal dynamics of the data as applied to time series.

This paper compares practical methods suitable for large-scale imputation of missing data implemented in Python. A method for predicting solar radiation as a time series using the ARIMA autoregression model is also proposed.

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CONTENT

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