Analysis of Barriers to the Development of Industrial Internet of Things Technology and Ways to Overcome Them

Vadim Zhmud
Dept. of Automation,
Head of Department
Novosibirsk State Technical University
Novosibirsk, Russia
oao_nips@bk.ru,
ORCID ID 0000-0002-1708-9211
IEEE member, ID: 95001934

Aleksandr Liapidevskiy
General Director of Novosibirsk
Institute of Program Systems,
Novosibirsk, Russia
nips@nips.ru
http://nips.ru/komanda

Valery Avrmachuk
School of Information Technology and
Robotics. Department of Automation
and Robotics
Tomsk Polytechnic University
Tomsk, Russia
avs@tpu.ru

Vitaly Sayapin
Director of R&D Center in Novosibirsk
Institute of Program Systems
Novosibirsk, Russia
v.sayapin@nips.ru

Oleg Stukach
National Research University Higher
School of Economics
and the Novosibirsk State Technical
University
Novosibirsk, Moscow, Russia
tomsk@ieee.org

Hubert Roth
Faculty of Natural Sciences and
Technology
University of Siegen,
Siegen, Germany
hubert.roth@uni-siegen.de

***Abstract*—The development of the digital economy requires the compilation of a roadmap for the development of all the end-to-end technologies included in the cluster of technologies that need to be developed to a new level. At the first stage, anticipating decisions on state financing of this cluster, a list of critical end-to-end technologies is compiled. The second step is the preparation of roadmaps for each of the selected critical technologies. As a rule, many experts are involved in drawing up roadmaps, including foreign experts. As a rule, the team of such experts is headed by an organization that has received instructions to develop a roadmap on a competitive basis. Of course, not all the wishes of all experts are taken into account by such an organization; therefore, there may be alternative opinions and alternative roadmaps, or additions to the developed roadmaps. If the roadmap developed by the governing organization is approved, alternative documents are only of perhaps scientific interest. If the roadmap developed by the core team of experts is not approved due to its insufficient completeness, the decision seems to be postponed, and the specified roadmap should be corrected by adding information from alternative documents, which, of course, should be done taking into account the opinion of all experts in the field. Since the approved roadmap for the "Industrial Internet of Things" direction does not yet exist, the authors consider it useful to present their position on this issue**

Keywords—automated control systems, sensors, actuators, smart city, smart production, telecommunication service, digital economics

I. Introduction

This paper provides an analysis of the prospects for the development of the critical end-to-end technology Industrial Internet of Things (IIoT), which is one of the most important technologies of the Digital Economy of Russia Program [1, 2]. Since the roadmap in this area has not yet been approved, the contribution of this publication to its development may be useful. The main issues to be solved are the compilation of a list of critical sub-technologies, the identification of barriers to their development or impeding the implementation of specific projects, as well as finding a list of activities that would eliminate these barriers, or reduce the risks of their negative impact, or reduce the damage from their impact.

II. Statement of the Problem

This paper solves the following tasks: analyzing the factors of technological supply, drawing up a list of sub-technologies, drawing up a list of technological and other barriers that impede the implementation of work provided by the roadmap and drawing up a list of measures to reduce the negative impact of these barriers.

First, the basic definitions should be given.

Internet of Things (IoT) – is system of combined computer networks and connected physical objects (things) with embedded sensors and software for data collection and exchange, with the possibility of remote control and management in an automated mode, without human intervention.

IIoT – is Internet of things for corporate or industry use, system of integrated computer networks and connected industrial (production) facilities with built-in sensors and software for collecting and exchanging data, with the possibility of remote control and control in automatic mode, without human intervention.

In terms of information management and processing technologies, the necessary changes are as follows:

- implementation of the ACS software logic as interacting cloud services ("management cloud", "IoT platform");

- the transition from rigidly hierarchically aligned information-isolated automated control systems to direct,

IEEE 978-1-7281-2896-2/19/$31.00 © 2019 IEEE

without human intervention and intermediate automatic control systems, the connection of management objects to the "management cloud".

III. Analysis of technological supply factors

IIoT devices use complex multi-level algorithms based on modern mathematical apparatus.

The use of neural networks in IIoT allows you to manage risks, build production efficiency forecasts, simulate any part of the production chain, etc.

In IIoT devices, large time delays are unacceptable: information is provided in real time with a delay not exceeding tens of milliseconds.

IIoT devices can generate large amounts of traffic, up to 1 PB (petabyte) per day.

IIoT devices by reducing routine activities that require manual operations lead to the fact that old jobs are closed and vacancies appear for highly qualified specialists who are able to design and maintain smart industrial systems, as well as analyze incoming information.

In the case of IIoT devices, any introduction to the infrastructure of an enterprise can provoke a real catastrophe, so ensuring security in this case is crucial.

IIoT solutions have a high cost due to the large number of devices required for installation in production. In addition, IIoT devices are expensive because they place high demands on reliability, safety, and performance in various (often aggressive) conditions. The decision in favor of introducing IIoT in production is made on the basis of the economic efficiency of such a step.

For IIoT, implementation is slow, since very often it requires a complete renovation of the production infrastructure. For the introduction of IIoT is characterized by a phased approach. The proposed solutions should take into account the possible scalability, modernization and compatibility with some parts of the old infrastructure.

Maintenance of IIoT devices is expensive, since the solutions used are complex, it is often very difficult to replace them, and the failure of parts leads to the suspension or complete cessation of production.

In the case of IIoT, failure of the mechanisms or failure of part of the network will lead to serious problems, and production will suffer significant losses or completely stop.

IIoT focuses on production benefits and allows you to increase business profitability. This is an improvement of the existing production telemetry and telematics systems at a qualitatively new level, the benefits of which arise only as a result of the synergistic effect.

Do not confuse the use of the Internet for industrial purposes and the creation of special Internet technologies for the industry. These approaches are fundamentally different ones.

IV. Some problems of drawing up a final list of sub-technologies

According to the State Corporation "Rosatom" Atlas [1, 2], there is one list of critical sub-technologies. According to the results of the work of various expert groups, there are other lists.

It includes sub-technologies [link to the atlas], which was supplemented by an expert council:

1. Device identification technologies (Machine identification)

2. Machine Sensory (Machine / device sensing)

3. Machine to Machine Communication (Machine2machine (m2m) communication)

4. Computing on devices (On-device computation)

5. Services, platforms, data collection (data gathering) and integration with devices

6. Smart & embedded devices (systems), semantics for devices

7. Industrial big data

8. Electronic component base (ADSP, ADC, DAC, PLL, etc.)

9. Middle layer: controllers, etc. (single-board and single-chip controllers, etc.).

10. Drives and actuators (including intelligent drives, stepper motors with a control system, mechatronic modules using MEMS technology, sensors using MEMS technology, micro and nano motors with a control system, etc.)

11. Means to guarantee information security management teams, data and other information at all levels.

12. Actually Internet technologies implemented on domestic equipment and software according to industrial standards

V. Another group of experts offers a different list:

1. Sensor equipment (sensors of production equipment and processes (incl. Process safety), bionic sensors, sensors for monitoring finished products);

2. Communication networks (modems wireless / modems wired, protocols and wired / wireless communication standards);

3. Industrial Internet platform (industrial DBMS, analytics (predictive) systems, data storage systems, industrial artificial intelligence systems, digital models and doubles);

4. Computing equipment for the operation of the IIOT platforms (server equipment, electronic component base);

5. Visualization tools and human-machine interaction (display technologies, decision support systems);

6. Information security (software encryption, hardware encryption). Taking into account the existence within the framework of the Digital Economy program of a separate area "Information Security", the detailed study will not be carried out within the framework of the Industrial Industry DC.

Despite the fact that there are approximately the same positions, some items are completely different. It would be necessary to decide on the final list before moving further in this direction. The problem is that even the same group of developers in different parts of their proposals uses different lists, for example, there is such a list.

1. The operational level of digital technology in the industry. Sub-technology "Sensor equipment".

2. The communication level of digital technology in industry. Sub-technology "Communication Networks".

3. The level of industrial digital platforms. Sub-technology "Industrial Internet Platforms".

4. The hardware level of digital platforms. Sub-technology "Computer technology for the operation of the IIOT platforms".

5. The level of industrial digital applications. Sub-technology "Visualization tools and human-machine interaction".

VI. The Practical Example

Nowadays there is a frequently situation when production facilities are underused or the production process is not profitable completely. It is more correct to operate on reduction of costs. Accordingly, all technologies directed this one are priority: such technologies included optimizing the production processes and increasing their efficiency. First of all, pay attention to big data. There are two reasons for this. At first, big data is not unique to production companies for a long time. But comprehensive analysis is still not carried out. The second reason is that the data is a system-forming component of the production process. When implementing the IoT paradigm, first of all it is necessary to build an effective system for analyzing the data and making management decisions based on facts.

For example is optimization of the electric submersible pump installation in Gazpromneft-Vostok [15]. The general population was studied, over thousand observations (installations). The company carried out a systematic work to reduce the installation time. At the same time, very interesting conclusions have not been identified yet, due a specialist in statistical methods did not work with the data.

The dispersion analysis in “Statistica” Factorial ANOVA module highlighted an issue concern degree of influence of season and deposit on duration of installation [16]. The average values of duration are noticeably higher for the Zapadno-Krapivinsky and Shinginsky deposits, but there is no seasonal effect for the Shinginsky deposit (Fig. 1).

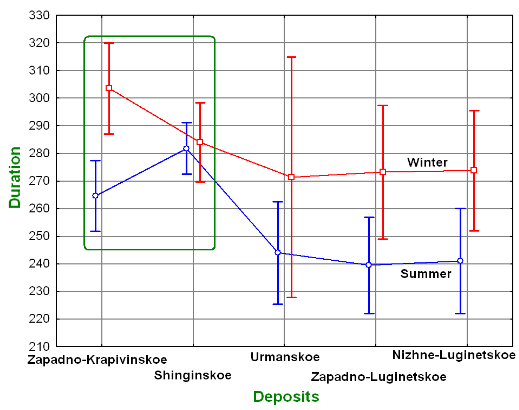

Fig. 1. Average values of installation time by deposits seasonal effects

This directly implies the conclusion that the advanced experience of electric submersible pump installation at the Nizhne-Luginetsky deposit should be adopted in Zapadno-Krapivinsky and Shinginsky.

Time of deinstallation for the electric submersible pump installation for repair was analyzed on the basis of the automatically collected data (Fig. 2). The company systematically works to reduce this time. But we do not pay attention to the absolute value of this time, it is more important how much is the large variability which does not decreased. Consequently, the further work should be aimed at reducing the variability of the deinstallation process using total quality management methods.

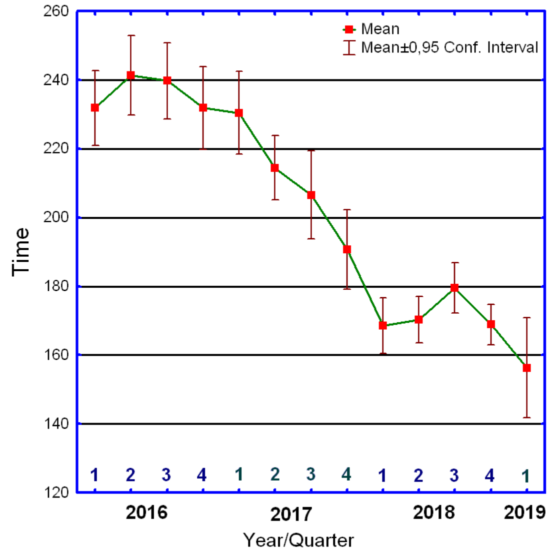

Fig. 2. The average deinstallation time for quarters and years

We also analyzed data from submersible pump installations from more than 1,500 wells. According to results, we highlighted a number of interesting conclusions. For example, it was found that with automatic start-up of pumps, saving of time for reaching the operating mode is achieved up to 15 to 30 minutes compared to manual start. Maybe someone say that 15 minutes is a few. In fact, it is some additional oil, the volume of which in a whole can reach thousands barrels.

It was interesting to compare the turnaround maintenance scheduling of the submersible pump installations for different years (Fig. 3).

We used the Kaplan-Meier survival analysis, implemented in the Statistica software. Compared with 2014, in 2017 it was possible to double the turnaround maintenance time. In 2018 and 2019 this work continues.

So the statistical methods are an advanced analytics for management decisions. We turn a huge amount of data into the analytical and statistical models that support adjust technological modes and find out when equipment needs repairing, what probability equipment fails, what are the influencing factors, and how they can be avoided.

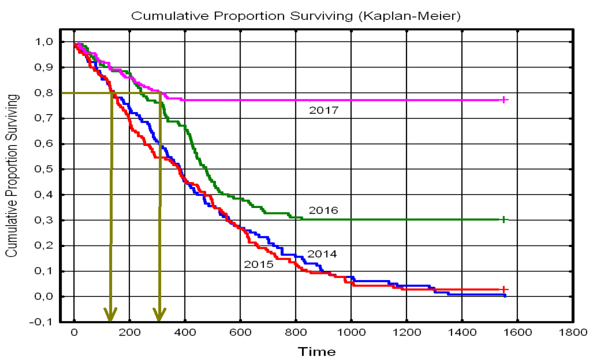

Fig. 3. Turnaround maintenance time for wells

VII. Proposed Solution

The situation, as a rule, is such that every expert involved in drawing up a roadmap suggests developing, first of all, the areas in which he himself intends to work. Also, each expert supports the directions proposed by friendly organizations and experts. Accents are placed not quite rightly.

Our vision consists in the following considerations.

1. “Industrial Internet of Things” technologies are not technologies that are based on using the existing Internet to solve existing industrial problems. If these technologies are mistakenly identified, then it can be argued that they already exist and are being effectively used. For example, Internet technologies are known and widely used for selling tickets for all types of transport, for booking hotels, for exchanging files that represent not only text documents, but also videos, photos, as well as any technological files, such as files for printing boards of electronic products, files for the production of parts on machine tools with programmed control and so on. Using the Internet as a means of delivering any kind of information in amounts sufficient for almost any modern technological problem is not new, it is not a new technology. Also, one should not include in these technologies reading sensors of the housing and utilities sector (determination of water, electricity, heating costs). It may seem to an unprepared reader that this is precisely the technology of the industrial Internet, but these are just a few practical options for using the traditional Internet for the traditional purposes for which it was created.

2. The appearance of the definition “industrial” in combination with the terms “Internet of Things” indicates that here we are talking about some new technological quality. It should be not only about improving the speed of communication lines, increasing the volume of file storages and expanding applications in the same direction in which they are already developing (and quite successfully without special funding to support the development of technologies in this particular direction). Here it is necessary to plan the creation of an alternative technological set of solutions, even if they use already existing hardware solutions for communication, for example, the same optical fibers. This decision should be completely independent of the provider of services on the trivial Internet, the rights and technical factors of owning such technologies should belong to the public sector or a consortium of manufacturers, which would ensure their independence from the proprietary rights of foreign states. This is fundamentally important: firstly, the Internet should be different, better, more reliable, faster, and secondly, it should be own from beginning to end, in all aspects of ensuring its uninterrupted functioning.

3. Control of the technological process and process of distant measurement is very important. There are many spheres of science and technologies where it is the most important to collect information with the use of Internet [3–12]. But even in the task of monitoring of the Earth Crust with the goal of finding of the possible earthquakes’ precursors can allow delay of several minutes or even several hours [13–14], however the real IIoT should be as swift as possible.

VIII. The List of Risks and Limitations That Can Narrow the Possibilities for the Development of Sub-Technologies

The main threats to using IIoT are the following.

1. Threats of hacker attacks or viruses or virus-like software: a) slowdown due to protection against hacker attacks; b) violation of work and erroneous actions or inaction because of successful hacker attacks.

2. Threats of data loss or inadequate device actions from software errors.

3. Threats of information loss or inadequate actions of devices from hardware breakdowns, including temporary breakdowns and temporary blackouts of certain sections of the network.

4. Socially-oriented hacking or hacking using the weakness of the human factor.

5. Incorrect resource allocation due to erroneous prioritization or conflict of priorities.

6. Insufficiently efficient use of resources due to insufficient awareness of software and hardware about the possibilities (defects in algorithms, approaches or means of communication).

7. Underreporting of hidden side effects from decentralization of management (failure to take into account the conditions, requirements, restrictions, standards or other factors in decentralized management).

8. Insufficient completeness of product standards used in IIoT.

9. Insufficient legal base and insufficient feasibility and other substantiation of IIoT concepts and individual technical solutions.

10. Extremely long implementation time for IIoT solutions (even compared with the pace of implementation of IoT technology solutions).

11. The difficulty of ensuring the compatibility of low-level devices with devices of the middle level and between themselves (as a consequence of the lack of standards for low-level products).

12. The difficulty of ensuring the compatibility of mid-level devices with devices of the lower and higher levels and between themselves (as a consequence of the lack of standards for products of the middle level).

13. The difficulty of ensuring compatibility of devices of the highest level with devices of the middle level and among themselves (as a result of the lack of standards for products of the highest level)

14. The danger of losing control due to the lack of legal responsibility for each specific level - the blurring of responsibility between an infinite number of users, providers etc.

15. Dependence on foreign technologies (software and hardware), on foreign hardware and software products.

16. The inability to reduce delays below a certain fixed level due to the geographical extent of the networks, which imposes its physical limitations.

17. The need for duplication (creating digital twins, backup data centers, etc.) to eliminate dependence on the reliability of all hardware.

IX. The main measures to reduce damage from threats when using IIoT are

1. Creation of fundamentally different networks (rejection of the use of existing Internet networks) based on technical solutions, excluding the possibility of hacker attacks.

2. Development and use of new methods for checking errors or inadequate actions of operators or new software components, improving test methods for newly introduced software, software quarantines, etc.

3. Development of hardware of increased reliability, including through duplication and redundancy.

4. Development of technical means of protection from socially-oriented hacks or hacks using the weaknesses of the human factor along with the development of instructions for users, taking into account the possibility of such hacks, widespread informing users about the content of such instructions.

5. Optimal resource allocation through proper prioritization and elimination of conflict of priorities, the use of multi-agent optimization methods, logistics of information flows, etc.

6. Efficient use of resources through the development of software tools for reporting on the use of released resources.

7. Development of standards and protocols for taking into account conditions, requirements, restrictions, standards or other factors in decentralized management.

8. Development of additional standards for products used in IIoT, their approval, mandatory compliance (legislative force, and not recommendatory).

9. Improvement of the legal base and preparation of feasibility and other substantiation of IIoT concepts and individual technical solutions.

10. Reduction in terms of implementation of IIoT solutions due to parallelization of work during their preliminary standardization, purchase of the element base, benefits for enterprises that have implemented IIoT solutions

11. Development and adoption of standards for the compatibility of lower-level devices with devices of the middle level and among themselves.

12. Development and adoption of standards for compatibility of lower-level devices with devices of the lower and higher levels and among themselves.

13. Development and adoption of standards for the compatibility of lower-level devices with devices and among themselves.

14. Developing a legal framework for localizing legal responsibility for each specific level, eliminating the vagueness of responsibility between multiple users, providers etc.

15. Reduction of dependence on foreign technologies through the development of domestic analogues and the transition to their use everywhere.

16. Use of advanced wired, optical and wireless technologies.

17. Implementation of duplication (creating digital twins, backup data centers, etc.) with regard to the priorities of the tasks to be solved (double, triple), along with the creation of information protection technologies without the use of duplication (for tasks with lower priority).

X. Areas of implementation of industrial Internet of things technology

In the Atlas there are only three directions for the implementation of these technologies:

1. Computer, electronic and optical equipment.

2. Telecommunication services.

3. Software products and software development services; consulting and similar information technology services.

In our opinion, this is too narrow a list. This list is based on the assumption that the industrial Internet has a focus only for itself. In fact, the industrial Internet is designed to improve production in all sectors of economic activity. Therefore, this list should include almost all types of economic activity, namely, according to the list below.

1. Products of agriculture, forestry and fisheries

2. Products of mining industries

3. Products manufacturing industries

4. Electricity, gas, steam and air conditioning

5. Water supply; sewage, waste disposal and reclamation services

6. Structures and construction works

7. Wholesale and retail services; repair services for motor vehicles and motorcycles

8. Transportation and warehousing services

9. Hotel and catering services

10. Information and communication services

11. Financial and insurance services

12. Real Estate Services

13. Services related to scientific, engineering and professional activities

14. Administrative and support services

15. Services in the field of public administration and military security; compulsory social security services

16. Education services

17. Health and social services

18. Services in the field of art, entertainment, recreation and sports

19. Services of public organizations; other services for the population

20. Various goods and services produced by households for own consumption, including employer services for domestic staff.

21. Services provided by extraterritorial organizations and bodies.

CONCLUSION

The development of the digital economy of the Russian Federation without a roadmap for the development of all end-to-end technologies is impossible. Many experts sometimes cannot agree on the most important positions of this roadmap, but plans and deadlines oblige them to move on. In this situation, when the movement goes further without solving important starting issues, chaos accumulates in it. One can quite accurately predict what will happen if, under the flag of the development of the industrial Internet, the development of the use of the existing Internet in existing areas of the industry, where it is already paying off, is financed. Instead of fundamentally new technologies, trivial technologies will develop in breadth, first they will be warehouses, inventory of various actions, document flow etc. The Internet will continue to be used where the delay for several hours and even for several days is uncritical, while the industrial Internet is a technology that excludes a delay for minutes, it should be about seconds and even smaller delay intervals. The authors believe that their opinion may be useful for the work of the next expert group.

REFERENCES

[1] Proektnyj ofis Cifrovaya ekonomika RF. GK Rosatom. Podgotovil-pilotnuyu versiyu doklada Atlas skvoznyx texnologij Tsifrovoj ekonomiki Rossii. (In Rus.) URL: http://digitalrosatom.ru/proektnyj-ofis-cifrovaya-ekonomika-rf-gk-rosatom-podgotovil-pilotnuyu-versiyu-doklada-atlas-skvoznyx-texnologij-cifrovoj-ekonomiki-rossii/ Date: 06.05.2019.

[2] Atlas-skvoznyye-tekhnologii-tsifrovoy-ekonomiki-Rossii. (In Rus.) URL: http://digitalrosatom.ru/wp-content/uploads/2019/01/%D0%90%D1%82%D0%BB%D0%B0%D1%81-%D1%81%D0%BA%D0%B2%D0%BE%D0%B7%D0%BD%D1%8B%D0%B5-%D1%82%D0%B5%D1%85%D0%BD%D0%BE%D0%BB%D0%BE%D0%B3%D0%B8%D0%B8-%D1%86%D0%B8%D1%84%D1%80%D0%BE%D0%B2%D0%BE%D0%B9-%D1%8D%D0%BA%D0%BE%D0%BD%D0%BE%D0%BC%D0%B8%D0%BA%D0%B8-%D0%A0%D0%BE%D1%81%D1%81%D0%B8%D0%B8.pdf. Date: 06.05.2019.

[3] The design of the control system for object with delay and interval-given parameters. Zhmud, V., Zavorin, A.20152015 Int. Siberian Conference on Control and Communications, SIBCON 2015 – Proc.. 7147060. URL: https://ieeexplore.ieee.org/document/7147060

[4] Method of sensitivity rise of laser vibrometers. Goncharenko, A.M., Vasil'ev, V.A., Zhmud', V.A.2003. Avtometriya. 39(2), p. 43-47. URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-0038469916&origin=inward&txGid=84da3eb356a301e23052c52a3636d7d8

[5] Absolute frequency measurements in precision laser spectroscopy of Muonium. Bagayev, S.N., Belkin, A.M., Dychkov, A.S., (...), Zakharyash, V.F., Zhmud, V.A. 1999. Proceedings of SPIE - The International Society for Optical Engineering. 3736, p. 310-318. https://www.spiedigitallibrary.org/conference-proceedings-of-spie/3736/0000/Absolute-frequency-measurements-in-precision-laser-spectroscopy-of-muonium/10.1117/12.340131.short?SSO=1

[6] Frequency reference in the 732-nm region for precision laser spectroscopy of muonium. Bagaev, S.N., Belkin, A.M., Dychkov, A.S., (...),Farnosov, S.A., Fateev, N.V. 2000. Quantum Electronics. 30(7), pp. 641-646. URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-33747921104&origin=inward&txGid=1737175b080350110dec7e8bb7c1eb13

[7] A phase-locked loop system for the difference frequency of two lasers. Barmasov, S.V., Zhmud', V.A. 2000. Instruments and Experimental Techniques. 43(3), p. 381-383. URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-0001213233&origin=inward&txGid=ec9f0cb6972124b8a33d461dfd9ac13b

[8] Development of rotating pendulum stabilization algorithm and research of system properties with the controller. Sablina, G.V., Stazhilov, I.V., Zhmud, V.A. 2017. 2016 13th Int. Scientific-Technical Conf. on Actual Problems of Electronic Instrument Engineering, APEIE 2016 – Proceedings. 3,7807046, p. 165-170. URL: https://ieeexplore.ieee.org/document/7807046

[9] Modern key techologies in automatics: Structures and numerical optimization of regulators. Zhmud, V., Yadrishnikov, O., Poloshchuk, A.,Zavorin, A.2012. Proceedings - 2012 7th Int. Forum on Strategic Technology, IFOST 2012. 6357804. URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-84871848099&origin=inward&txGid=c055246e783ba6ad54cf3463ac7e9591

[10] Modern problems of high-precision measurements of the phase differences. Zhmud, V.A., Goncharenko, A.M. 20162016 13th Int. Scientific-Technical Conf. on Actual Problems of Electronic Instrument Engineering, APEIE 2016 – Proceedings. 1,7802284, pp. 314-318. URL: https://ieeexplore.ieee.org/document/7802284

[11] Real time digital super-high accuracy vibrations measurements: Methods, devices and mathematical modeling for the metrology. Zhmud, V., Liapidevskiy, A.2010. Proceedings of the IASTED International Conference on Modelling, Identification and Control. pp. 343-347. URL: https://ieeexplore.ieee.org/document/7802284

[12] An electronic system for stabilizing the frequency of the He-Ne laser to the methane absorption lines. Zhmud, V.A., Barmasov, S.V., Gitel'son, V.D. 1999. Instruments and Experimental Techniques. 42(4), pp. 551-557. URL: https://ieeexplore.ieee.org/document/8545475

[13] Modification of optoelectronic intellectual systems for absolute measurements in monitoring of earth seismic dynamics. Zhmud, V., Semibalamut, V., Dimitrov, L.,Taichenachev, A. 2017 Int. Multidisciplinary Scientific GeoConf. Surveying Geology and Mining Ecology Management, SGEM. 17(21), pp. 999-1004. URL: https://www.sgem.org/sgemlib/spip.php?rubrique318&debut_articles_rubrique=10#pagination_articles_rubrique

[14] The increase of the accuracy of the laser-based measurement of ultra-low tidal deformation of rocks. Zhmud, V., Semibalamut, V., Dimitrov, L., Fomin, Y. 2017 Int. Multidisciplinary Scientific GeoConf. Surveying Geology and Mining Ecology Management, SGEM. 17(21), pp. 1069-1076. URL: https://www.sgem.org/sgemlib/spip.php?rubrique318#pagination_articles_rubrique

[15] O.V. Stukach, M.V. Moiseenko, V.V. Zhuralvev, A.A. Panov, A.V. Tretiakov, P.V. Rabunets, "Statistical optimization of duration for the electric submersible pump installation". Dynamics of systems, Mechanisms and Machines, 2018, vol. 6, no. 3, p. 91-96. DOI: 10.25206/2310-9793-2018-6-3-91-96. https://elibrary.ru/item.asp?id=36422159.

[16] Borikov V.N., Stukach O.V., Popova E.A., "Control of the Microplasma Process in Electrolyte Solutions Based on STATISTICA Model". 2007 Int. Siberian Conf. on Control and Communications (SIBCON-2007). The Tomsk IEEE Chapter & Student Branch. Russia, Tomsk, April 20-21, 2007. P. 58–63. IEEE Catalog N 07EX1367. ISBN 1-4244-0346-4. http://ieeexplore.ieee.org/document/4233277/.