



Digitalization of the Russian Energy Sector: State-of-the-art and Potential for Future Research

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ABSTRACT

In this paper, we review forty seven best papers on digitalization of the Russian fuel and energy complex. All the papers are written in Russian and published in a number of Russian academic journals that are mostly distributed via closed national library systems and, consequently, are not available for foreign scholars interested in studying Russia's energy policies. Our review identifies a total of five research directions in the Russian scholarship: (1) General trends in digitalization of the Russian fuel and energy complex; (2) concepts and approaches used by the Russian scholars; (3) government policies; (4) digital technologies; and (5) security concerns. Each research direction is carefully covered and analyzed. Then, we identify gaps in the Russian scholarship and propose three potential research areas.

Keywords: Digitalization, Energy Industries, Russia, Contemporary Scholarship

JEL Classifications: Q2, Q3, Q4

1. INTRODUCTION

One of the key topics discusses in the contemporary scholarship is the development of digital technologies and their introduction into the energy sector (Di Silvestre et al., 2018; Truby, 2018; Goldbach et al., 2018; Andoni et al., 2019). Russia is no exception. Issues of digitalization of the country's fuel and energy complex are addressed at all levels of the Government. In particular, the Government of Russia has developed ambitious plans of building a digital economy in the country and ensuring further digitalization of the energy and fuel complex (Government of Russia, 2017). As is often emphasized by the leading officials in the Government of Russia (Ministry of Energy, 2018), the development of policies aimed at digitalization in the energy sector are based on expert analysis and cutting-edge scholarship. It is worth mentioning that the most significant volume of research on Russia's energy and

fuel complex, including issues of its digitalization, is published in Russian in the Russian journal. More than that, this research is not available via largest scholarly repositories and databases, such as SSRN, RePEc, EBSCO, ProQuest, and others. Many of the titles are distributed solely via Russian libraries. Only some journals are available by subscription via eLIBRARY.ru, the Russian language electronic library of scholarly literature.

Consequently, the wider research community has no access to the scholarship written in Russian and distributed only in closed national systems. However, in order to understand and evaluate policies aimed at the digitalization of the fuel and energy complex of one of the largest energy producers in the world, one should have an understanding of the key trends existing in the Russian scholarship, which eventually lay down into expert evaluations and policies adopted by the Russian Government. In this paper

we review the leading Russian scholarship focused on federal policies aimed at digitalization of the fuel and energy complex of Russia, analyze the key research areas covered, and propose the further research avenues.

In order to select the best papers on digitalization of the fuel and energy complex of Russia, we used resources of the Russian Science Citation Index available the eLIBRARY.ru platform (RSCI, 2019). In particular, we identified and reviewed the most cited papers. Particularly, we covered the following journals: *Energeticheskaya Politika* (Energy Policy), *Neftyanoe Khozyaistvo* (Oil Industry), *Atomnaya Energiya* (Atomic Energy), *Tekhnologii Nefti i Gaza* (Oil & Gas Technologies), *Izvestiya Rossiyskoi Akademii Nauk Energetika* (News of the Russian Academy of Sciences – Energy), *Vestnik Uralskogo Gosudarstvennogo Universiteta Seriya Energetika* (Bulletin of the Ural State University - Energy Series), *Avtomatizatsiya i IT v Neftgazovoy Oblasti* (Automation and IT in the Oil and Gas Industry), and many others. In total, forty seven papers are covered in our review and rigorously analyzed.

According to the paper focus, our preliminary analysis allowed us to group them in the following research directions: (1) General trends in digitalization of the Russian fuel and energy complex; (2) concepts, strategies, and approaches used by Russian scholars; (3) government policies; (4) digital technologies; and (5) security concerns. Thus, the paper gives a snapshot of the Russian scholarship on the topic under analysis and describes the key research direction covered.

The paper proceeds as follows. First, we review the Russian scholarship on digitalization of the fuel and energy complex according to the sections outlined above. In particular, we focus on each of five research directions outlined above. On the basis of the review, we analyze gaps and drawbacks existing in the research and propose further research agenda. Then we conclude with final remarks.

2. THE STATE-OF-THE-ART IN THE RUSSIAN SCHOLARSHIP ON DIGITALIZATION OF THE ENERGY SECTOR

This section of the paper reviews the Russian scholarship on digitalization of the national fuel and energy complex by focusing on the following: (1) General trends in digitalization, (2) concepts and approaches outlined, (3) government policies, (4) digital technologies, and (5) security concerns. After conducting the review, we discuss potential avenues for future research on digitalization of the Russian fuel and energy complex.

2.1. General Trends in Digitalization of the Russian Fuel and Energy Complex

The first Group of papers covers general trends in digitalization of the Russian fuel and energy complex. In particular, the authors focus in the issues of increasing competitiveness because of the great impact of digital technologies on almost all spheres of the energy sector. Given the primary role of the fuel and energy

complex in the Russian economy, the importance of digitalizing this branch of the national economy is hard to overestimate.

In particular, (Tekslar, 2018) argues that the global technological race is a serious challenge for companies and countries seeking to maintain their competitiveness and leadership at the global level. It is associated primarily with the speed and scale of the development and distribution of digital and intellectual technologies in all areas of the economy and social life. For Russia, active participation in this technological competition is a matter of the country's future (Abukova et al., 2017c). Since Russia is one of the main exporters of energy in the world, the use of digital technologies opens up completely new opportunities and obvious economic benefits in all sectors of the fuel and energy complex. This stimulates financial investments of energy companies in technologies such as robotization, the Internet of things (IoT), artificial intelligence, etc., as argued by (Dmitrievsky, 2016; Voyko, 2018).

A number of papers discuss particular prospects of Russia's energy sector digitalization, focusing on practical applications of digital technologies in almost all spheres. Thus, (Abukova et al., 2017b) argues that intellectual and digital technologies increase the accuracy of geological exploration and drilling of wells, significantly reduce the number of errors in equipment design and operation, warn of possible failures and accidents at industrial facilities, provide continuous monitoring and optimization of the entire production process from production to energy supply to the consumer.

These digital technologies are used at a number of fuel and energy facilities. Several dozens of "smart" wells and fields are already functioning in the Russian oil and gas complex, digital twins are being introduced (Tekslar, 2018). Sensors and portable devices are actively used in the coal industry (Abukova et al., 2017b). They allow to determine the level of gas pollution in mines, the state of technology and the location of workers. Digital technologies are used especially actively in the power industry of Russia, (Matveev, 2018) states. For instance, monitoring and prediction systems for generating equipment, digital dispatching of energy facilities are being introduced, and digital substations, smart grids are being built, making it possible to cover entire areas. The introduction of digital and intelligent technologies in the fuel and energy sectors not only reduces production costs and increases the reliability of the power systems, according to (Tekslar, 2018; Amirkhanova, 2018), but also provides an impetus for large-scale technological breakthroughs in related industries. To increase the scientific and technical potential of the country, preserve and enhance its competitiveness, it is important not to borrow foreign technological solutions but to create our own breakthrough technologies, including in the field of digitalization in the energy sector (Dmitrievsky et al., 2016).

Some scholars, when discussing general trends in digitalization of the fuel and energy complex of Russia, prefer to focus on particular subsectors. For instance, (Massel, 2018) focuses on the ongoing digital transformation of the electric power industry, arguing that the main trends include the large-scale use of distributed renewable energy, attracting private investment in the intellectualization

of the industry's infrastructure, the formation of decentralized markets, and new active consumer behavior patterns of people who are increasingly turning into "smart" energy suppliers. The complexity of digital transformation in Russia is due not only to global external challenges but also to the peculiarities in the development of the Russian electric power industry, such as vast territory with low population density in certain regions of the country, excess of traditional fuel and energy resources, underdevelopment of competition in domestic energy markets, and other socio-economic factors (Massel, 2018).

However, the process of digitalization of the economy and energy not only opens up fundamentally new opportunities for development but also brings new serious challenges and risks, a number of scholars argue (Fortov and Makarov, 2013; Abukova et al., 2017a; Filippov, 2018). For instance, the increasing complexity of the power systems themselves creates a problem of reliable control. The risk appears to be the non-integrable technologies when the implementation takes place in the production of various hardware components and digital software. Increasingly sophisticated cyber-attacks require increased attention to protecting the power systems from them. The digitization of the economy inevitably leads to a reformatting of the labor market. The vocational education system is to be changed significantly and must have sufficient time to adapt to these changes (Abukova et al., 2018). According to (Tekler, 2018), the digital transformation will inevitably lead to a significant change in business models, the entire fuel and energy complex and energy markets.

According to (Massel, 2018), a number of challenges inevitably arise when Russia attempts to digitalize its fuel and energy complex. These challenges, as (Massel, 2018) argues, can be conditionally divided into cognitive and managerial challenges, personnel challenges, and scientific and technological limitations. Cognitive and managerial challenges are expressed in the absence of: (1) A concept and a holistic view at the state level (imbalance arises from this between the strategic goals of the state and tactical objectives, leading to the imitation of innovative activity in the country); (2) a mechanism for coordinating the interests of all subjects of the electric power industry; (3) the legal framework that would introduce stimulated digital technologies; (4) economic incentives for the transition to the digital power industry. Scientific and technological limitations consist in the absence of problem-oriented professional communities (scientists, engineers), where discussions would be about problems and prospects of applying digital technologies in the energy sector. These scientific and technological constraints make the transition to digital energy difficult. The same scientific and technological limitations are in the shortage of scientific research and experimental development in the field of digital energy, in an insufficient number of digital devices at power facilities, the lack of development of a unified methodology for assessing the effect of introducing elements of digital energy, etc. (Massel, 2018).

2.2. Concepts and Approaches

With the purpose to describe and explain processes of digitalization of the Russian fuel and energy complex, scholars rely on a variety of concepts and approaches (Tsvetkov et al., 2014; Obert and

Sindtukov, 2014; Dmitrievskiy and Eremin, 2015; Eremin et al., 2015; Shchetinina, 2017; Holkin and Chausov, 2018; Filippov, 2018; Grabchak et al., 2018; Ivanter, 2018; Veselov and Dorofeev, 2018; Panov et al., 2018). In this section of the paper, we would like to review the concepts of (1) "3D" (Decarbonization, Decentralization, and Digitalization), (2) "digital energy," (3) "Internet of energy," (4) "information environment," (5) "intelligent power systems," and (6) "intellectual energy systems."

According to Holkin and Chausov, 2018, the concept of "3D" (decarbonization, decentralization, digitalization) gives the most holistic view of the transformation of energy in the near future. Decarbonization provides for a transition to a "carbon-free" (i.e., environmentally friendly) economy by increasing the share of renewable energy in the energy balance, reducing the use of fossil energy resources, and developing electric transport. Decentralization means the transition to a geographically distributed power industry with a large number of multi-level generators and consumers, the emergence of new subjects of the electric power industry. These subjects are the so-called "prosumers," who are both producers and active consumers. Digitalization implies the widespread use of digital controlled devices connected to the Internet at all levels of the power system, from generators and distribution networks to end users (Tsvetkov et al., 2014). This creates the possibility of intelligent control of power systems based on machine-to-machine (M2M) interaction. All three processes are interrelated in this concept. Creation of reserve generating and/or accumulative capacities is required during a large-scale transition to renewable energy. A cardinal approach to solving the problem of growing energy inefficiency is based on the transition to a decentralized organization of capacity, management, and energy markets (Obert and Sindtukov, 2014; Holkin and Chausov, 2018). This decentralized capacity organization effectively combines large and small distributed energy and ensures the satisfaction of dynamically changing consumer demands. Thus, authors conclude that digitalization is an effective tool for managing such a complex system as the decentralized distributed energy system (Eremin et al., 2015; Shchetinina, 2017).

The essential characteristics of digital energy are described by (Holkin and Chausov, 2018). First, the essence of digital energy is the change and development of the entire set of industrial and economic relations between people, companies, and public institutions based on digital approaches and tools. Second, reducing the growing costs of integrating distributed energy and market transactions is the main task of digital energy. Third, digitalization in the energy sector means the creation of new business models, services, and markets based on digital modeling and M2M interactions. Demand aggregators, virtual power plants, energy hedging, virtual distributed energy storage, etc are the business models that already exist in the world (Abukova, 2017a; 2017b). Fourth, the cyber-physical nature is a characteristic feature of the digital economy and energy, which is due to the fact that smart machines (cyber-physical systems) are able to make operational decisions without participation of people. When making decisions, they are guided not by rigid algorithms but by a set of goals determined by people and digital models (Holkin and

Chausov, 2018). Fifth, the liberation of a person from machine functions (when a person has turned into an appendage of a machine) and the creation of favorable conditions for truly creative human activity in various fields of activity will occur due to the rapid development of digital energy (Holkin and Chausov, 2018).

A number of Russian scholars (Dmitrievskiy and Eremin, 2015; Holkin and Chausov, 2018; Grabchak et al., 2018) note that the concept of “digital energy” is strongly connected to other concepts and approaches: Internet of Energy, Transactive Energy, Energy Cloud, FREEDM Systems, etc. The concept “Internet of energy” describes the digital transition in the energy sector and is considered as the basis for building an energy Internet architecture (Holkin and Chausov, 2018). This can lead to the formation of such an energy system that would become transactional, intelligent, stable, and flexible. The conceptual model of the Internet of energy is based on the concept of “energy cloud,” as (Panov et al., 2018) and (Holkin and Chausov, 2018) argue. The Internet of energy is viewed as an ecosystem of technically and economically interconnected users. At the same time, the Internet distributed energy is a system of systems. It is a combination of the following three systems: (1) Systems of smart contracts (formation, control, execution and payment), also often being called “Transactive Energy” (TE); (2) systems of M2M interactions and exchange of control effects between energy cells and energy equipment of the IoT; (3) systems for maintaining the power balance and ensuring the static and dynamic stability of the Neural Grid power system (Holkin and Chausov, 2018).

Another Group of scholars, particularly (Grabchak et al., 2018), argue that the transition to a digital economy in Russia is to be accompanied by the formation of new links in the general information environment, because the open exchange of digital data in a single digital space and the use of platform solutions are its main principle. It promotes horizontal and vertical integration both within a separate subject of the economy and the industry, as well as within the national economy as a whole. The power industry digitalization, according to (Grabchak et al., 2018) should lead to the creation of a unified information field, including the formation of a unified conceptual information model of the entire power system, i.e., the unified distributed technological interaction environment. This environment is built on a network-centric principle with decentralized control. In the same way, the processes of digitization in the electric power industry should lead to the transformation of the existing control models by using the capabilities of digital technologies, such as accelerating data exchange, increasing the transparency and reliability of information, continuous digital design, including digital forecasting and planning models, etc. (Chichev and Glinkin, 2010; Dmitrievskiy and Eremin, 2015; Grabchak et al., 2018).

“Intelligent electric power systems” is another concept actively used in the Russian scholarship to discuss challenges to and prospects of digitalization in the energy sector. According to (Veselov and Dorofeev, 2018), an intelligent electric power system is a synthesis, integration of information and electric power systems (networks) as a single infrastructure for the power supply. This infrastructure has a completely new functionality, they argue.

In particular, the formation of an intelligent power system is a complex engineering, economic, and organizational task, because provides for a large-scale replacement of all power equipment and a transition to new generations of process control systems and market operations at all levels based on upgrading: automation, information, and intelligence of control systems (Borisov and Borisova, 2011; Veselov and Dorofeev, 2018). In essence, this is the realization of an intensive scenario of the development of the whole electric power industry. According to (Semenistaya and Leonova, 2018), the transition to the intelligent electric power systems is most efficiently done not from the “top down” but from the “bottom up,” i.e. from consumers and local power supply systems. And at the same time, it is necessary to create distributed clusters of new energy and a new market environment (Veselov and Dorofeev, 2018; Semenistaya and Leonova, 2018).

2.3. Government Policies

Despite there is no paper in the Russian scholarship that would be fully devoted to analyzing federal or regional policies aimed at digitalization of the fuel and energy complex, a number of papers cover this topic superficially (Skryl, 2009; Iseeva, 2009; Moroz, 2012; ACGRF, 2013; Veselov and Dorofeev, 2018; Teksler, 2018; Pavlenko et al., 2018; Holkin and Chausov, 2018; Oganov et al., 2018; Grabchak et al., 2018).

For instance, some Russian scholars argue that this is highly necessary to adopt a special government program on digitalization of the national fuel and energy complex (Holkin and Chausov, 2018). And such a program should accompany the already adopted Program “Digital Economy of the Russian Federation” (Government of Russia, 2017) and the Presidential Decree “On the National Goals and Strategic Objectives of the Federation for the period until 2024” (President of Russia, 2018).

Another scholar, (Teksler, 2018) states that the foundation has already been laid for digital transformations in the Russian fuel and energy complex. In particular, the “technology roadmap” has been in place to introduce innovative technologies and modern materials in the sectors of the fuel and energy complex in the Russian Ministry of Energy since 2014. In addition, the Forecast of the Scientific and technological Development of the Branches of the Fuel and Energy Complex of Russia for the period until 2035 was developed (Ministry of Energy, 2016). This document has a section on digitalization of the energy sector of Russia. Two dozen innovative projects are implemented within the framework of the roadmap. Also, (Teksler, 2018) notes that the Government of Russia has been actively implementing the National Technology Initiative “EnergyNET” since 2016 with the purpose of developing intellectual energy services. The basic idea of EnergyNET is to create a new image of the grid and the energy market that meets current and future challenges (EnergyNET, n.d.).

Within the large scope of their research, (Veselov and Dorofeev, 2018) emphasize the need to develop and implement sufficient policies at the federal and regional levels aimed at developing the intellectual power system in Russia. According to these scholars, this is a new type of power system that should

have: (1) Minimal restrictions for the integration of any objects of production, accumulation, and consumption of electricity into the general electric network; (2) high adaptability of the system to external conditions; (3) a customer-oriented nature, giving priority to the interests of consumers (Veselov and Dorofeev, 2018).

Another priority is emphasized by (Grabchak et al., 2018). They argue that the balance of interests of all technologically interconnected subjects of the industry are to be taken into account in the course of the digital transformation of the electric power industry. Therefore, a proper national strategy should be the basis for developing corporate strategies, concepts and programs for digitization of the electric power industry in Russia. More than that, (Grabchak et al., 2018) that the creation of conditions and incentives for the development of domestic production, the development and introduction of Russian digital technologies, and the increasing investment attractiveness of industry projects should be among the priority tasks.

2.4. Digital Technologies

A great number of papers are devoted to various digital technologies that can be used in the fuel and energy complex of Russia, including intelligent energy technologies (Borisov and Borisova, 2011; Lazeev et al., 2018), smart oil and gas technologies (Dmitrievsky and Eremin, 2015; Dmitrievsky and Eremin, 2016; Ulyanov et al., 2017; Eremin et al., 2017; Dmitrievsky and Eremin, 2018; Stolyarov et al., 2018; Dmitrievsky et al., 2018), active consumer technologies (Kucherov et al., 2018), digital control systems (Loginov and Raikov, 2015), digital information systems (Sitnikov et al., 2014), and digital cognitive technologies (Yakovlev et al., 2017).

Of particular interest is the paper written by (Starchenko et al., 2018). In that piece of work, the authors argue that the rapid development of machine-to-machine (M2M) communications, the IoT, big data analysis, and management systems based on artificial intelligence (AI) become combined with the advent of energy storage systems, the development of micro-networks, and the affordability of equipment for distributed generation. The basic principles on which carbon energy has hitherto been built lose their meaning. The traditional vertical arrangement of power systems is transformed into a more flexible, reliable, and more economical distributed system, according to (Starchenko et al., 2018).

The impact of new digital technologies on the market is discussed by (Kucherov et al., 2018). They state that the transition to digital and intellectual electric power industry leads to the formation of a new cluster of smart active consumers. These consumers seek to benefit from the synergistic effect created by new breakthrough technologies. Fundamental changes in power supply systems contribute to this process, including the following: (1) The running process of maximally approaching distributed generation of electricity to its final consumer; (2) accumulation of excess electricity at the end user and their use in the local retail or wholesale electricity market; (3) building intelligent control systems for various objects of distributed generation, including ensuring their compatibility. Such new control objects, according to (Kucherov et al., 2018), belong to the cluster of active consumers, such as: Controlled load, energy storage systems,

electric transport, “smart” home, micro power plants, virtual power plants, flexible distribution networks, etc.

Another research collective focuses attention on the use of blockchain in the fuel and energy complex of Russia (Gumenny and Maslennikova, 2018). Blockchain is a universal technology that provides a large set of commercial transactions in various fields, including in the energy sector. In particular, they propose to use cryptocurrency based on nuclear power plants and hydroelectric power plants, where there is an excess of capacity and energy. A company with excess energy can provide it to another company and get additional profit by selling cryptocurrency on the market. In addition, (Sidorenko et al., 2018) focus on the same issue but in application to the coal industry.

2.5. Security Concerns

The accelerating processes of digitalization in the Russian fuel and energy complex force the scientific community of Russia to increase their attention at security issues associated with the use of digital technologies in the energy sector. (Voropai et al., 2018) critically review a set of emerging security issues in the electric power systems caused by the increasing use of complex digital technologies. Other scholars (Massel and Gaskova, 2018) discuss cybersecurity threats in the fuel and energy complex, arguing that Russia should adopt a new cybersecurity doctrine.

3. POTENTIAL FOR FURTHER RESEARCH

Our review demonstrates that the Russian scholars actively study the whole range of issues related to digitalization of the fuel and energy complex of Russia. Despite the variety of topics already covered in the Russian scholarship, there are still gaps in the body of knowledge. First of all, given the importance of digitalization of Russia’s energy sector for the country’s political and economic leadership, it is surprising that there is no single paper fully devoted to an in-depth analysis of the current and prospect government policies aimed at digitalization. We would like also to note that there is nothing published in the Russian academic journals on government management systems in the field of digitalization of the fuel and energy complex. Consequently, this important topic is simply neglected and not researched. Second, the rise of digital platforms that offer decentralized, digitally enabled exchange of energy from distributed sources in Russia’s energy sector is of great academic interest and practical importance. Unfortunately, this set of issues, and especially in application to urban and rural energy systems, is not properly studied and evaluated. Third, perspective research projects, in our perspective, would provide in-depth insights into the place of digital technologies and digitalization processes in the overall structure of energy industries in Russia. Such a wider focus on digitalization is simply necessary for developing and implementing macro-policies in the fuel and energy complex of Russia.

4. CONCLUSION

The research conducted allowed us to carefully review a total of five research directions in the Russian scholarship on digitalization

of the national energy sector: (1) General trends in digitalization of the Russian fuel and energy complex; (2) concepts and approaches used by the Russian scholars; (3) government policies; (4) digital technologies; and (5) security concerns. Each direction was carefully reviewed. On the basis of the review, we identified three potential research areas: (1) Conducting an in-depth analysis of the current and prospect government policies aimed at digitalization of the energy sector; (2) focusing on the rise of digital platforms that offer decentralized, digitally enabled exchange of energy from distributed sources; and (3) provide in-depth insights into the place of digital technologies and digitalization processes in the overall structure of energy industries in Russia.

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