Scientific bases of digitalization of energy in conditions of digital economic transformation

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Abstract. The article is devoted to the study of measures aimed at the digitalization of the energy sector in the context of the digital transformation of the economy. The issues of the digital transformation of socio-economic systems are considered. The article analyzes the problems of the development of digital energy, as part of the concept of digital transformation of the economy, explores the concept of integration of information and communication technologies and the Internet of energy.

1 Introduction

Systematization and generalization of the views on the essence and content of digital transformation existing in theory and practice make it possible to form the author’s idea and interpretation of such a modern phenomenon as “digital transformation”, reveal its essence and determine the role in the development of economic systems [1-6, 10-11, 13-16].

According to the concept presented in 1993 by the mathematician Vernor Vinge at the Vision-21 symposium [1, 5, 13-16], the main approaches to the digital transformation of socio-economic systems at the present stage of the development of the digital economy can be defined as:

- Process approach, within which it is customary to consider the socio-economic system as a value chain from the development of a product / service to their implementation and maintenance.
- Sectoral approach, which puts forward the need to study the close relationship of socio-economic systems at various levels and sectors of the economy.
- A technological approach to the digital transformation of socio-economic systems involves the choice of a dynamic pool of technologies that contribute to accelerated digitalization and digital transformation of a particular socio-economic system. In the scientific literature, within each approach, the corresponding models of digital transformation are developed and presented. Changes in the quality and content of information do not occur as part of digitization, for subsequent processing in digital format, it is simply converted into electronic form, which allows you to improve existing business processes by adding information in digital format to them.

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2 Materials and methods

A review of the scientific literature shows that the problems of the development of digital energy (DE) are currently [11, 13-16]:

- Insufficiency of the national element base for the implementation of digital technologies.
- The need to ensure controllability, stability and survivability of energy systems, the properties of which are radically changing under the influence of intellectualization and digitalization of energy.
- The need for import substitution of both the main power equipment and the equipment of the information and communication control subsystem.
- Cybersecurity threats to energy systems.
- "Energy of big data" (supercomputer Summit (USA) - 15 MW).
- Insufficient regulatory framework for the development of digital energy.
- Insufficient regulatory framework for the development of digital energy the need for regular timely modernization of educational programs for the training of specialists who own modern IT and end-to-end DE technologies.

Internet energy (IoEN).

Implementation of energy infrastructure as decentralized networks of direct transactional energy, information and economic interaction of all participants in the energy market with minimal costs:

- The organizational and technical principles of the modern Internet are applied in the Internet of Energy;
- NB: The first Internet technologies in the 1990s were designed according to analogies with large energy (cf. GRID computing).

At present, the development of the architecture and technologies of the Internet of Energy is carried out within the framework of NTI "Energynet".

The transition to the Internet of Energy requires the solution of scientific and technical problems and the development of new technologies in the following areas:

- Automatic machine-to-machine communication (Internet of Things).
- Automatic regime control and stability maintenance (Neural Grid).
- Automatic economic transactions based on Smart contracts (Transactive Energy).

The Smart Grid Functional Model presented by the US National Institute of Standards and Technology (NIST) in 2009, identifies the main areas of activity in the electric power industry, represented by seven areas-domains, united by technological and communication links (Figure 1) [3-4, 6, 8, 13-16]:

- Bulk Generation.
- Transmission.
- Distribution.
- Operations.
- Customer.
- Markets.
- Service provider.
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The following are identified as the most progressive modern concepts of digital transformation in [5]: 1. Platform concept - a business model that has been formed in the process of digital transformation and is designed to function in the digital economy.

The content of the digital transformation process is shown in Figure 2.
within the framework of the concepts of the New Industrial Society of the 2nd generation and Noonomics was carried out by the Russian professor S.D. Bodrunov [5]. According to this concept, primary data must be pre-processed - turned into more or less structured information, from which, preferably by intelligent methods, the required knowledge must be extracted. This knowledge should be used to manage the respective facility.

From this point of view, digitalization can be considered as an evolutionary modern element of the chain "automation - informatization - digitalization". And the experience of successful automation and informatization in the energy industry is huge. End-to-end technology is a key scientific, technical/technological solution, the implementation of which provides a breakthrough and game-changing improvement in the industry's position in existing markets for works, products and services or contributes to the formation of new markets.

3 Results and Discussion

System projects of digital transformation of socio-economic systems:

- **Digital factory (factory) (smart factory, virtual factory).** The "Digital Factory" is closely linked to the concepts of "Industry 4.0" and "Digital Manufacturing" (digital manufacturing). Initiatives to create the Factories of the Future are supported, in particular, in the countries of the European Union.

  “As part of the Horizon 2020 technological development program, pilot projects of Digital Factories are being created on the basis of such companies as Volkswagen (automotive industry, Germany), Siemens (electronics, Germany), AgustaWestland (helicopter industry, England, Italy), Consulgal (construction, Portugal). Digital factories (Digital Factory) in terms of the overall architecture of the Factories of the Future are the basis (an integral part) of the development of "Smart" (Smart) and Virtual (Virtual) factories.

  "End-to-end" and "sectoral" interpretations of digitalization.

  One of the key elements of the digital factory is additive manufacturing (layer-by-layer manufacturing), which is based on the manufacture of a product in layers based on a 3D computer model using 3d printing. According to Marcets&Marcets, by 2022 the 3D printing market will be worth more than $30 billion.

  “According to PWC estimates, in 2015, about 7% of industrial companies used 3D printers for the production of final industrial products, and another 7% of companies needed to implement this technology.” 3D printing is associated with the concept of decentralized (additive) manufacturing (distributed manufacturing).

- **Digital city (Smart City).** The Smart City concept is the concept of integrating information and communication technologies and the Internet of Things to manage city assets (schools, libraries, transport, hospitals, power plants, water and waste management systems, law enforcement and other public services). Arup, a global urban consulting firm, estimates that the global market for smart city services will be $400 billion a year by 2020. Collaborations are already being created around the world to create smart cities with the participation of the world's largest technology companies (Cisco, GE, Microsoft, Siemens, etc.).

  An example of such cooperation is the Chicago Digital City project. Construction companies show the greatest interest in the practical application of Smart City. In 2014, the largest Russian developer Morton (PIK Group), together with RVC, launched the Smart City initiative and searched for good practices to apply. The development company Kortros also implements construction projects in Yekaterinburg and Perm in the Smart City format. The concept of "Smart City" can also be represented as a set of industry projects.
Centralized management of the digital transformation of socio-economic systems at the state level through a single digital platform based on continuous monitoring of the market and consumers makes it possible to optimize local infrastructure and close the gap between regions. Among the main characteristics that a new digital institution should have, it is worth noting the following features of a single digital platform operating at the state level: centralized accounting of infrastructure facilities in the on-layn mode; management of infrastructure provision of regions, settlements, industries and end users; end-to-end analysis and centralized collection of reports; quick response to changing needs.

Standardization issues in the formation of digital energy (DE) is in the focus of attention of leading international organizations and institutions [3-4, 6-10, 13-16]:
- International Electrotechnical Commission – IEC.
- International Council on Large Electrical Systems – CIGRE.
- European committees for standardization – CEN and CENELEC.
- European Institute for Standardization in the field telecommunications – ETSI.
- Institute of Electrical and Electronics Engineers – IEEE.
- USA National Institute of Standards and Technology – NIST.
- Electric Power Research Institute – EPRI.

As noted in [13-16], a number of international standards on which the design and operation of Smart Grid elements can be based already exist (Figure 3).

**Fig. 3. IEC Standards for Control Systems.**

### 4 Conclusion

The proposals outlined in this article open up the prospect of further research, which is currently important, the problems of digitalization of the economy in the context of digital transformation and predetermine:
Digital technologies used in the world market are quite extensive and reflect global trends for their implementation. Innovators in the field of digital technologies in the global market are large financial institutions, IT companies, industrial companies, retail companies due to the availability of resources not only to adapt digital technologies to their needs and customer needs, but also due to their skills and readiness for organizational change.

The motivation of companies making the transition to digital technologies is explained by increasing competition in the markets, the need to provide customers with better digital services, as well as the desire of companies to reduce internal transaction costs.

The most preferred and cost-effective form of implementing digital transformation processes for the socio-economic systems of the economies of countries, in our opinion, is the use of the services of service integrator companies that provide digital services integrated into complex and universal digital platforms. The application of this approach to digital transformation is determined by the possibility of ensuring the consistency and complexity of the processes of digitalization and digital transformation.

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