Cloud technologies in energy

Yu V Konovalov¹ and O A Zasukhina²

¹ Assistant professor, kand. of tech. sciences Angarsk State Technical University, Angarsk, RF
² Angarsk State Technical University, Angarsk, RF
E-mail: yrvaskon@mail.ru

Abstract. A number of cloud technology features are specified in power engineering. Introduction of additional categories of cloud technologies and infrastructures taking into account the specifics of power engineering facilities was justified. The use of energy systems simulators as electrical energy systems digital twins when using cloud technologies of power systems advanced simulators, as MaaS cloud service for cloud computing deployment in IT-infrastructure of the energy community cloud is proposed.

1. Introduction
The energy sector is a core part of the developing industrial complex. Many companies, including energy ones, are encounter the problem of updating their IT infrastructure to increase performance when processing large data volumes. There is a need to study the impact of cloud technologies on the activities of these companies taking into account the production specifics at power generation facilities [1].

In relation to the power engineering facilities the advantages of 'clouds' are the availability of information in the joint document flow for the facility state for different services monitoring the operating mode, defining the service life of the facility, scheduling repairs and replacement of devices when accessing databases, structured in the 'cloud'. Taking into account the distributed nature of electrical devices in the distribution networks of different configurations, information exchange through the cloud structure is also an undisputable advantage. An important element is the ability to provide the required reliability for power facilities by specialized structures with the presence of additional power sources, security, professional employees, with continuous data backup, high resistance to DDOS-attacks.

As a result, cloud technologies are becoming increasingly important for power engineering companies with the ambition to grow and develop. The 'cloud' helps them get on-demand access to more data than ever before, and to increase computing capacity to obtain significant results and recommendations.

Despite the fact that cloud computing is considered a promising technology of the future, the power generation industry and electrical energy-based utilities are gradually moving to their adoption. The results of a study conducted by Oracle found that 45% of the industry enterprises are already using cloud technologies and 52% are planning to use them. Moreover, 69% of power generation companies reported that they are already using the cloud technologies to manage information about customers or already scheduled it for the next two to three years [2, 3].

2. Introduction of cloud technologies in power engineering
According to the data contained in the report of Oracle Utilities units 'On Cloud Now: Cloud Technologies are Here for Utilities', the first to implement cloud technologies are major energy
companies (72%), who are followed by small and medium-sized (50% and 23%, respectively) companies. Respondents noted that during transition to the cloud environment they consider the use of the software and providing hosting services [3].

The amounts of investment in this area are witnessed by the fact that in May 2016, the Oracle acquired the cloud services provider for power generating industry and Utilities – Opower for $532 million. In order to work with large data volumes the Opower platform stores and analyzes more than 600 billion readings from 60 million end users. This allows enterprises to comply with regulating authorities requirements in a timely manner, reduce maintenance cost and enhance customers satisfaction [4].

The processing of large data volumes may require the construction of new data processing centers (DPC), personnel selection, design, installation of basic and additional elements of the DPC that is associated with significant material costs. Moreover, there is a trend to build a backup DPC to protect IT infrastructure and to ensure its smooth operation regardless of force majeure and other factors [5]. The active development of cloud technology and virtualization are the alternative to this. Provides provide a 'cloud DPC' service, which allows to completely transfer the IT infrastructure to outsourcing, while maintaining a high level of scalability and reliability.

Independent research company Forrester Research predicts that the global cloud computing market in 2020 will be 241 billion, while in 2010 the figure was 40.7 billion dollars [6]. At the same time, the reduction of per unit costs for implementation of digital technologies is observed. Projects in the field of digitalization now cost 10 times cheaper than 5 years ago, and 100 times cheaper than 10 years ago [7, 8]. Exponential decline in the value of the means of production with a digital component is observed.

3. Infrastructure and categories of cloud technologies in the power engineering

The Forrester Research [6] has identified three major trends that will prevail in the next 10 years:

1. infrastructure cloud services;
2. providing software as a service;
3. virtualization.

The above trends in most cases [1, 9, 10] distinguish three levels or categories that differ from each other in that they adapt to the different customer needs:

1. The lowest level is called 'infrastructure as a service' (IaaS). At this level, users get basic computing resources, such as processors and data storage devices, and use them to create their own operating systems and applications.
2. The next level is the 'platform as a service' (PaaS). In this case, users have the ability to install their own applications on the platform provided by the service provider.
3. The highest level of cloud computing is called 'software as a service' (SaaS). It is this level that is currently of greatest interest. It should be noted that the cloud stores not only data but also the associated applications, and a user requires only a web browser.

In the power engineering, the formation of essentially new market services – consulting in this area, is underway now. The essence of cloud computing is that the consumer uses third-party resources as a service, transferring information to the cloud and remotely using means of processing and data storage. Data processing centers of the power generation industry must operate in a single cloud-IT space [1]. It should be noted that any of these DPC, which are a set of servers combined in cluster, is integrated, i.e. includes various types of cloud technologies. The DPC of network, power generating companies and system operator of the unified energy system should be linked with each other by different data transmission channel. This model is an integrated, combined and flexible, it contains both traditional data transmission channels and data transmission channels via cloud services. The electric power industry has its own specifics. On the one hand, the optimal solution of issues of energy management and energy control are necessary for the successful operation of the enterprise and its competitiveness.

On the other hand – in the course of digital transformation, it can be complicated by such characteristics of contemporary power systems as complexity and criticality. As analysts predict, the number of cloud services and solutions will increase. PaaS service should grow faster than other: according to the KPMG company forecast, it will increase from 32% in 2017 to 56% in 2020 [11].
Specifics of power generation industry [12-15] implies the introduction of additional categories of cloud computing:

4. For the natural development of cloud computing in the line of providing the consumer with the most ready-to-use computing service while using distributed and remote energy facilities is the level of 'Desktop as a Service' (DaaS) – a fully ready-to-use workbench.

5. If we move in the direction of maximum proximity to the use of real equipment, then the ultimate case will be 'Metal as a Service' (MaaS). In fact, MaaS is a lease of computing facilities, access to which meets the requirements of standards and accepted technologies.

For these purposes, you can configure a well-known dispatch control system in the cloud structure, collecting, processing, displaying and archiving information about the SCADA monitoring or control object (Supervisory Control And Data Acquisition). This system is a part of automated control system of power supply in the modern enterprise.

The existing electric energy systems (EES) including power plants, main network and distribution network, have a very complex structure. A variety of factors and operating parameters of installed equipment should be taken into account in their operation, maintenance and modernization. Accounting and recording of all parameters of the power system have become a very complex task and require the use of advanced tools and methods of research. This is especially important in transient and emergency modes to ensure reliable operation of microprocessor devices and systems of relay protection and automation which require verification of the calculated setpoints and testing of selected algorithms and operating logic. The solution to these problems is possible with the use of advanced simulation of power systems in the form MaaS cloud service when deploying cloud computing.

For example, known hardware-and-software RTDS simulator (Real-Time Digital Simulator) designed by RTDS Technologies Inc. (Canada) [16] enables simulation of electric networks and power generation plants in real time and provides communication with the connected equipment through the digital feedback channels.

PSCAD (Power Systems Computer Aided Design) designed by Manitoba HVDC Research Centre (Canada) [17] is similar to RTDS in terms of purpose and scope of the simulation. Simulator PSCAD is intended for studies of electromagnetic and electromechanical transient processes in AC and DC systems and it allows to develop models of electric energy generation, transmission and distribution systems. In the study of ultraspeed transient processes, PSCAD simulator can use cloud computing resources which would allow to work with digital twins in real-time without limiting the size of the simulated power system using a random calculation step based on the level of nanoseconds. In the version of PSCAD X4.6 the manufacturer already uses a new mechanism of granting licenses to any user for the use of PSCAD via the Internet through cloud technologies.

Contemporary electric power generation industry, at the next stage of its development, is transformed into the intellectual one, the so-called Smart Grid. At this stage, which has been underway for several years, the idea of a Smart Grid is being embodied in the electric power enterprises, including network ones.

The modern integrated concept of intellectual EES includes:

- advanced power components of EES controlled by systems that implement the vector control of the controlled parameters;
- advanced information and computer technologies based on cloud computing, the use of the concept of Industrial Internet of things;
- new tools and measurement technologies based on optical current and voltage transformers, transmission, processing and visualization of information via optical fiber lines or using 4G and 5G cellular technologies. These means and technologies provide Internet access to larger number of devices, thus minimizing delays in data transmission and ensuring ultra-fast speed;
- new proactive methods of solutions justification, methods and EES modes management means and the power consumption modes for power-consuming units.

Currently, the following deployment models of cloud computing [12, 18, 19] are distinguished: Public cloud – an IT infrastructure that offers low-cost opportunities for deploying own sites that allow
multiple scaling; Private cloud – a structure that is organized for use by a single organization; Hybrid cloud – an IT infrastructure which combines the qualities of public and private clouds.

For solving the tasks of increasing the effectiveness of network of the intellectual power engineering is an urgent and important to solve problems of complex integration in terms of cloud computing as well. For the power engineering, it is advisable to delegate to public cloud [19, 20, 21] power engineering specific properties and to represent energy cloud community as a cloud – a type of a cloud infrastructure that is designed for the exclusive use of cloud computing resources by a particular user community solving common tasks. Consumers of cloud-computing services included in the community have common requirements and the relationship with each other with regard to common tasks in the complex system of electricity supply quality control. The problem of effective management of the electricity supply quality requires a consistent solution of the whole range of multiparameter and interrelated issues aiming at optimization. Effective solution of these tasks to ensure the set modes of power consumption, power quality and reliability and solving the issues of electrical equipment operation, depends on the availability of sufficient baseline data on the EES status and on the interaction environment. The last requirement implies the existence of a powerful system of EES complex monitoring allowing to measure, collect, store, process, and appropriately represent information required to control power supply quality.

One of the main trends for energy companies to enhance reliability, and equipment operation quality is the implementation of modern strategy of proactive approach to maintenance and repair of equipment. The implementation is based on the calculation of indices of technical condition of equipment and integrated infrastructure facilities. In addition to assessing the condition of the equipment, the standard in this area is the use of techniques assessing the probability and consequences of equipment failure. The digital twin is configured in such a way, that the data from the SCADA systems, geographic information systems, and systems of asset management, were recorded into a single database CommonInformationModel (CIM) of energy community cloud. After data consolidation from different sources the power engineering companies will be able to apply intelligent analytics to extract meaningful information. Due to the wide data set, companies will be able to develop and use increasingly perfect analytical models in energy community cloud.

All this in conjunction, requires to change habitual paradigm of thinking and move to a proactive approach in the power systems operation: instead of 'waiting for' the accident and then controlling it in the emergency mode. The technological basis for this can be the 'PowerAdvisor' cloud service. At the initial stage, monitoring is carried out, EES data are collected and uploaded to the 'cloud'. Then digital hierarchical model of EES is built and data analysis is performed to find potential problems and a report is generated on the basis of which the customer takes action. At the final stage, 'PowerAdvisor' checks, whether shortcomings are removed, and if necessary, generates new recommendations.

4. Features of cloud technologies in power engineering

With all its advantages, cloud technologies, with regard to power engineering facilities, have a number of specific features:

- to gain access to cloud services a constant connection to the Internet is required. However, nowadays, it's not such a big disadvantage, especially with the advent of 4G and 5G cellular technologies. To enhance computational performance, annual increase in bandwidth of data communication networks increases by about 3 times [18];
- there are restrictions on software that can be deployed to the 'clouds' and provide it to the user;
- currently, there is no technology that would guarantee 100% confidentiality of stored data;
- the loss of information in the 'cloud' means that it cannot be restored;
- the 'cloud' itself is a fairly reliable system, but when intruding it, the intruder gains access to the huge data storage which is unacceptable for energy, providing electricity and heat supply to facilities with high categories of reliability;
- to build the own cloud, it is necessary to allocate significant material resources;
- in addition, modern equipment is functioning together with other, already obsolete equipment.
The analysis performed indicated that 25% of the electricity consumption management systems have outdated configurations that compromise the monitoring and EES control quality, 10-15% of the devices in a typical control system complete their life cycle, more than 15% of the facilities can potentially lead to equipment damage and unplanned downtime;  
• a significant characteristic energy systems is their conventional importance. For example, the effectiveness of the power utilizing organization can have a significant impact on its budget and malfunctioning in the power system is able to endanger employees or the company property. In DPC industry, this sum can reach 750 thousand Euro for the event, and in the telecommunications sector – 30 thousand Euro per minute [22].

5. New possibilities of cloud technologies in power engineering
Application of cloud technologies in the power engineering allows:
• to reduce the power consumption for servicing their own IT infrastructure;
• to implement a proactive approach in the operation of power engineering facilities;
• to use the opportunities of scalability, mobility and availability of IT services, achieve operational energy audit, increase success level, efficiency and effectiveness in the functioning of the entire power generation industry as a whole;
• to increase the efficiency of the power generation industry by creating a single information center specializing in the collection, processing and analysis of data on the technical condition of all facilities of the industry. This can be implemented by management a new specific model for deploying cloud computing – the ‘energy community cloud’. This approach contributes to a more rapid solution to the problems of collecting and analyzing data on industry facilities, with the wide use of cloud technologies and achievements in the field of artificial intelligence and, in particular, the formation of knowledge bases for quick and high-quality decision-making, which is extremely important for the functioning of active-adaptive network and implementing the concept of a fully controlled SmartGrid;
• to increase the productivity of power generation companies both to increase operational efficiency and to reduce the negative impact on the environment. Since artificial intelligence, machine learning, and big data analysis technologies continue to improve, energy companies can go down to the bottom of their data to make important advances in their development in all lines;
• introduce the concept of the Industrial Internet of things (IIoT), which allows to increase the efficiency of industrial and technological processes with an overall reduction in capital costs [23, 24]. IIoT will allow power supply companies to reduce energy shortages in the network, reduce maintenance and repair costs, and improve methods for predicting technological failures in equipment operation.

References
[1] Shaykhutdinov A M 2015 Opportunities for using cloud technologies in the energy sector Modern scientific research and innovation No 2 p 3 Retrieved from: http://web.snauka.ru/issues/2015/02/45646 (accessed: 02/20/2020)
[2] Cloud, fog and edge computing: differences and prospects of technologies development Retrieved from: https://rb.ru/story/edge-computing (accessed: 02/14/2020)
[3] Oracle study: most energy and utilities companies use cloud services Retrieved from: https://servernews.ru/938393 (accessed: 02/14/2020)
[4] Energy sector and Utility companies are actively explore cloud technologies Retrieved from: https://www.searchengines.ru/otrasl-energetiki-i-zkh-aktivno-osvaivat.html (accessed: 02/14/2020)
[5] Critically important technologies for power generation market Retrieved from: https://clck.ru/JpKTN (accessed: 02/14/2020)
[6] The Cloud Computing Playbook for 2020 Retrieved from: https://www.forrester.com/The Cloud Computing Playbook/-/E-PLA102 (accessed: 03/01/2020)
[7] Mozokhin A E and Shvedenko V N 2019 Analysis of the directions of digitalization development of home and foreign energy systems Scientific and technical bulletin of information
technologies, mechanics and optics 19 No. 4 pp 657–672 (Preprint doi: 10.17586/2226-1494-2019-4-4-657-672)

[8] Khokhlov A, Melnikov Yu, Veselov F, Khoklin D and Datsko K 2018 Distributed power generation in Russia: development potential p 87 Retrieved from: https://energy.skolkovo.ru/downloads/documents/SEneC/Research/SKOLKOVO_EneC_DER-3.0_2018.02.01.pdf (accessed: 03/01/2020)

[9] Reese J 2011 Cloud computing (SPb.: BHV-Petersburg) p 288

[10] Fingar P 2011 Dot. Cloud: cloud computing - business platform of the XXI cent. (Aquamarine book – M) p 256

[11] Power generation dashes to the 'cloud' Retrieved from: https://www.kommersant.ru/doc/3745157 (accessed: 02/02/2020)

[12] Belonozhko P P, Belous V V, Kutsievich N A and Khramov DА 2016 Free cloud hardware and software platforms Analytical review Internet journal 'SCIENCE STUDIES' 8 No. 6 Retrieved from: http://naukovedenie.ru/PDF/61TVN616.pdf (accessed: 02/02/2020)

[13] Glushchenko P V 2020 Prospects for cloud technologies in mathematical and instrumental methods of research and management in the intellectual power engineering complex of Russian economy Retrieved from: https://cyberleninka.ru/article/n/perspektivy-oblachnyh-tehnologiy-v-matematicheskih-i-instrumentalnyh-metodah-issledovaniya-i-upravleniya-v-intellektualnom/viewer (accessed: 02/02/2020)

[14] Chernyak L 2008 HPC, Fifteen years of evolution Open systems No 4 Retrieved from: http://www.osp.ru/os/2008/04/5114370/ (accessed: 03/01/2020)

[15] Puppet, Chef, Orchestration and DevOps Au courant technology Retrieved from: https://aucouranton.com/2013/07/31/puppet-chef-orchestration-and-devops/ (accessed: 03/01/2020)

[16] Technologies Inc Retrieved from:https://www.rtds.com/ (accessed: 03/01/2020)

[17] PSCAD Retrieved from:https://www.pscad.com/ (accessed: 03/01/2020)

[18] Sudakova L Yu 2013 Evolution of 'computing cloud' technologies and the strategy of their governmental support in the USA Digest-finance No 2 pp 45-56

[19] GOST ISO/IEC 17788-2016 Informational technologies (IT). Cloud computing. General provisions and terminology Retrieved from: http://docs.cntd.ru/document/1200141425 (accessed: 02/26/2020)

[20] Tabachnikova T V, Nurbosynov D N, Bashyrov R F, Bashyrov R F, Batanin A V 2019 Simulation model of the electrical complex of auxiliary equipment of an oil and gas production enterprise International Scientific Electric Power Conference (IOP Publishing. IOP Conf. Series: Materials Science and Engineering) p 643 (Preprint 012096 doi:10.1088/1757-899X/643/1/012096)

[21] Tabachnikova T V, Macht A D, Nurbosynov E D 2019 Analytical studies of transformers operating modes in supply and distribution electric network of a field substation International Scientific Electric Power Conference (IOP Conf. Series: Materials Science and Engineering) p 643 (Preprint012090 doi:10.1088/1757-899X/643/1/012090)

[22] Do you know how much a power outage costs a large company? Interview with the Head of Solutions for Improving the Quality of Power Supply Schneider Electric KKiriil Kokoulin, Retrieved from: https://www.facebook.com/SchneiderElectricRU/ (accessed: 01/05/2020)

[23] Duan Y Li W, Zhong Y and Fu X 2016 A multi-network control framework based on industrial internet of things Proc. IEEE 13th Int. Conf. on Networking Sensing and Control (ICNSC). (Preprintdo: 10.1109/ICNSC.2016.7479021)

[24] Jayaram A 2017 An IIoT quality global enterprise inventory management model for automation and demand forecasting based on cloud Proc. Int. Conf. on Computing, Communication and Automation (ICCCA)(Greater Noida, India) pp 1258–1263 (Preprint doi: 10.1109/CCEAA.2017.8230011)