Chapter

Blockchain Technology in the Field of Energetics: Organization of Effective Energy Market

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Abstract

The article is devoted to the topic of blockchain applications in the field of energetics. A role of the technology in the digital economy development has been discussed; corresponding examples from Russian, Chinese, Estonian experience have been presented. A synergy between usage of blockchain and other information technology such as big data, intelligent avatars and the Internet of things has been demonstrated. Implementation of the blockchain technology into the functional scheme of the energy market has been proposed as a ways to ensure its decentralization and openness. Energy supply contracts can be negotiated directly between producers and consumers without intermediaries, so all the market actors have a high level of autonomy in purchasing and selling. The technology provides services for preparation and issuance of necessary invoices, as well as for making settlements for the entire transaction. Blockchain technology ensures economic and information security of transaction participants and includes convenient tools for realization of their market activities. Difficulties and risks, connected with the technology implementation, have been discussed, as well as main ways of its further development.

Keywords: blockchain technology, energy market, digital economy, decision making, distributed data, intelligent avatar

1. Introduction

In the mass consciousness, the term "blockchain" is associated with cryptocurrencies and financial mechanisms for avoiding centralized control over deposits. However, this view is too narrow. The blockchain is a technology for organizing distributed databases and transaction systems, associated with the databases, which should ensure reliable data storage and a possibility of their distributed processing [1]. The development of this technology supposes solution of many interdisciplinary problems in the field of cryptography, mathematics, Internet technologies and computer programming [2]. Blockchain, to put it simply, is a shared ledger, distributed over a special network, which fixes all transactions and guarantees correctness and safety of data.

A feature of the blockchain is that the confirmation of correctness of actions and accompanied data does not require involvement of a special third-party organization, as is the case of traditional transactions [3]. The validity of any actor, operating in the market, (trading organization or individual) is confirmed by validity of a node in the blockchain, which must be present in the network and visible throughout it.

There are several levels in the blockchain structure: data level; network level; consensus level; the level of incentives; contract level; and application level. The data level encapsulates kernel data and algorithms, associated with data encryption and timestamping. The data is an encrypted series of decimal digits that are decrypted using timestamps.

The network level includes methods of data distribution in the network and data validation. The consensus level includes methods of generating and distributing economic reasons, integrating by such way economic factors into the blockchain technology system. The level of contracts encapsulates various algorithms for concluding and implementing contracts (smart contracts). The application level includes other algorithms, that are not assigned to the listed levels, but are necessary in a particular blockchain models. The main innovations of the blockchain technology are the followings: the block structure; the use of timestamps; distributed node consensus mechanism; inclusion in the model of "economic reasons"; flexible and programmable smart contracts.

The following main areas of blockchain application can be distinguished now: financial system; insurance business; logistics; Internet of Things (IoT) [4]; public services [5]; social security; education [6]; digital copyright. We especially note that the implementation of the blockchain technology makes a powerful impact on the development of international financial and trade cooperation.

Evident nowadays leader in blockchain's applications is the financial sector. The Internet finance is moving to the forefront of the global financial system, being the driving force behind the introduction of new information technologies into the global economy. Along with the use of big data, mobile Internet, cloud computing, etc., blockchain is becoming the basis for the development of financial technologies.

Among the important areas, where the use of blockchain is becoming commonplace, one can also mention the energy industry [7] and, first of all, the energy market [8, 9]. Informatization of the energy market can give a significant synergistic effect for the development of national and global economies [10]. Blockchain creates prerequisites for the decentralization of the energy market [11], which is long overdue. The decentralization has especially advanced in the electricity market, where producers and consumers can be geographically close and do not need in a centralized intermediary [12]. This is especially true for alternative sources of energy (solar, wind, etc.), which do not have high power and stability and, correspondingly, product of which must be consumed locally [13].

The development of the blockchain will be effective only in conjunction with the development of other modern information technologies, which, on the one hand, facilitate the implementation of the blockchain, and, on the other hand, allow the effective use of the results of using the blockchain for effective decision-making and the overall development of the energy sector.

2. Synergy of blockchain and other IT

In modern conditions, blockchain technology, within the framework of general approaches to the development of the digital economy [14], should be combined with other information technologies [15]. These are, first of all, big data technology, which must be used when deploying ultra-long blockchains. Development of some blockchain services involves using artificial intelligence systems. And important to mention, that the blockchain is a technology, which is capable of integrating into IoT as its information kernel and means for communication between individual networks [16].

One of the most important functions of the blockchain is to support transactions and contracts. The objectivity and reliability of used artificial intelligence tools should minimize the possibility of error or misuse of these functions. When forming and implementing smart contracts, it must be guaranteed that the system saves all their parameters and leaves indelible timestamps.

Any transaction must be confirmed by both sides, and in many cases two intelligent bots (two "avatars") can take over this function. If one of the sides, after corresponding analysis, decides not to confirm the transaction, it is automatically canceled. In turn, the blockchain will provide sufficiently complete and reliable information for the avatars, which make the decision. The passed information can be filtered; the blockchain can have its own algorithms for filtering incoming information; it can be recognized as a spam, or as an informational recommendation, or as a direct command.

Avatar, as artificial intelligence (AI) software, is based on algorithms of self-learning neural networks and functions in close connection with an automatically generated knowledge base (KB) [17], in the development of which the blockchain is involved. KB includes both a block of basic knowledge and a constantly growing block of experimental knowledge, accumulated new information about observed specific processes and situations. In turn, the structure of KB can be based on blockchain technology [18, 19], which supports distributed and reliable storage of information, as well as information security of big data in the process of their collection, transmission and storage.

The use of AI systems are important also for authorizing and profiling blockchain users, as well as for monitoring their activities.

The development of IoT also needs the use of blockchain, as there is a problem of paying for centralized services, the support of which becomes unbearable for operating companies because of the geometric growth of IoT. Blockchain technology can provide collection and direct transmission of data without organizing a special centralized accounting system.

In addition, there is the problem of IoT privacy, since the centralized architecture involves centralized storage and transmission of all information, which can lead to large-scale data leaks. In this regard, distributed encryption in the blockchain makes client privacy more strong, since collecting and decrypting distributed data is technically much more difficult than hacking a central server.

Another issue stems from the fact that, under the current IoT architecture, clients can only perform network transactions on their own or trusted networks. This limitation, which greatly reduces the commercial value of the Internet of Things, can be circumvented by using the blockchain. For example, the "autonomous centralized remote control between centers", developed jointly by IBM and Samsung, uses a special blockchain registration to enable IoT devices to directly interact with each other and implement complex business logic.

3. Blockchain in energy

Data aggregation, their reliable distributed storage and possibility of imposing certain business functionality on them are in demand in the energy sector. First of all, the blockchain is used to ensure the decentralization of the energy system. Energy supply contracts can be negotiated directly between producers and consumers, so that both parties have a high degree of autonomy and do not need intermediaries. Drawing up contracts and making transactions is automated and provided with a sufficiently high information security system. All actions are recorded and can always be checked if the parties wish.

There are several areas of blockchain applications in the energy sector. First, as already mentioned, it is organization of the energy market. At present, it is quite complex organizationally and chaotic. At the global level, it is highly influenced by political factors. Some suppliers can appear or disappear on the market, depending on the political situation in their countries (for example, Libya, Syria, Nigeria), sanctions regimes arise and end (against Iran, Venezuela, etc.), new norms of centralized regulation are introduced (like EU energy packages), etc. Of course, blockchain technology cannot change the general rules, but it can mitigate the consequences of sudden changes and allow the market to adapt to new conditions. Integration on a single technological decentralized platform of numerous market actors makes it easier for the buyer and seller to find each other, while avoiding many risks. By using blockchain currencies (such as USDT), automatic checking the participants of the transaction and its compliance with corresponding customs regulations, it is possible, according to experts' opinion, to reduce the duration of the transaction to less than 5 minutes.

The application of blockchain in the oil and gas industry is focused on replacing traditional "paper" trading in commodities with more transparent and cheaper "electronic" trading. VAKT, the world's first blockchain platform for oil trading, was created in 2018 and is a good example to follow. At the end of 2017, BP and Shell proposed "to build a digital blockchain platform based on commodity trading." The following year, a blockchain platform called VAKT was successfully developed and put into production, and the founding companies immediately used it to trade North Sea oil.

The introduction of blockchain technology facilitates the recording of reliable data on carbon emissions, which is now a matter of great importance. There is currently limited transparency in the global market regarding the methods, used to measure and predict emissions, and there is a problem of trust in available information. Blockchain can provide greater confidence in data from global carbon inventories and registries.

Another area, promising for the use of blockchain, is the exploration and organization of oil and gas production. It is known that the corresponding business processes are multilevel and involve a wide variety of actors. Exploration is not limited to just searching for a deposit; in parallel, the cost of launching operation and the further profitability of production should be assessed. During the whole process, it is necessary to take into account numerous geological, geographical, physical, chemical, demographic, economic, technological and financial factors (starting from the depth and thickness of the field and finishing with the cost of credit funds). Data is collected by all participants of the process, (starting from geologists and finishing by financiers), and must reach the stakeholders in an adapted form. The blockchain system can provide significant assistance in this.

A well-organized distributed database facilitates the process and reduces costs. Already at the exploration stage, geologists receive from the blockchain the meteorological and seismic information, and intelligent avatars are able to suggest (basing on available, previously collected data) where, when and how to start exploration.

Thanks to the constant real-time putting new data into the blockchain, recommendations are constantly refined, which reduces the likelihood of errors in oil drilling modes and accelerates the progress of the project. Already in the course of oil and gas production, monitoring of critical parameters allows you to quickly conduct an economic analysis and calculate such parameters as the cost of energy resources, the life of the well, etc. Blockchain technology makes it possible to ensure targeted access to information, its use for various, in particular, scientific purposes, without the risk of leakage of its confidential part.

4. Distributed energy markets

One of the most promising ways to use the blockchain in the energy sector is the information support of the energy market in connection with the above-mentioned trend towards its decentralization. Flexible spatial distribution of generation and consumption of energy resources improves the quality of customer service, reduces operating costs and ensures reliable network operation. Given the growing demand for renewable energy and tightening control of carbon dioxide emissions, the production of electricity on microgrids with blockchain information support is becoming increasingly important in the development of the energy sector [20].

In the operation of a microgrid blockchain, it is especially important to provide an appropriate transaction mechanism and implement optimization of a microgrid power output. In order to achieve the lowest total cost of a microgrid blockchain, a two-way transaction mechanism and corresponding smart contracts are usually used.

There is no perfect centralized transaction information support model that would provide complete trust in terms of ensuring the interests of all parties. Blockchain technology largely combines the properties of reliability, transparency and security. Distributed decentralization helps organize low-cost and highly efficient power distribution work, solving problems of trust and energy efficiency [21, 22].

The microgrid blockchain can increase or decrease the contribution of a node according to real needs, which is carried out using a transaction mechanism and ensures energy optimization. Such a flexible mechanism is especially important for "renewable energy sources" such as photovoltaic, wind, tidal, etc. Renewable energy sources are unstable and cannot work effectively in isolation. For them, the stabilizing function of the blockchain is critical.

Let us consider the transactional architecture of the microgrid blockchain and propose one of its possible efficient architectures. The general structure of the energy blockchain consists of many microgrids and several large power grids connected on a point-to-point basis (P2P). Each node of the blockchain network can turn on and trade through the network. Each microgrid corresponds to one specific type of energy device: a photovoltaic array, a wind turbine, and so on. The microgrid also includes energy storage equipment (batteries). When energy generation is insufficient, batteries give out energy, and when generation is excessive, it is stored. The users of the microgrid blockchain are consumers of household energy and owners of electric vehicles.

In the blockchain, the distribution of energy among the numerous microgrid users is controlled by a special control block. The structure of energy transactions represents a "microgrid – user" relationship, i.e. both parties trade according to a one-to-many structure. However, since the generation of renewable energy is largely influenced by natural conditions, and consumer behavior is relatively stable, then there is often a mismatch between electricity generation and demand in the trading link of the microgrid. When electricity production exceeds demand, the excess capacity must be sold to the outside world; when there is not enough electricity to meet the demand in the microgrid, electricity must be purchased from the outside. If this kind of relations will be carried out only with large power networks, this will increase unnecessary costs due to fixed prices at "wholesalers" and creates need to perform electricity transactions arrhythmically.

Unlike the structure of blockchain transactions with a single microgrid, in a multicomponent blockchain, each microgrid is located in parallel, independently of each other. On the electricity trading market, formed on the basis of multi-grid blockchain, the parties to each transaction are equivalent, regardless of belonging to a microgrid. In this case, the mechanism of "bilateral auctions" is being implemented, which ensures a high degree of market adaptation to changing economic and natural conditions. Bilateral smart contracts do not require participation of third-party institutions; direct transactions are not only simplified, but they also provide a greater level of confidentiality and independence. The chain data structure makes the data immutable and easy to check, and makes it easier to monitor the market.

Designing a blockchain structure of the market, after defining the overall architecture, implies the ability to model and optimize the power of the microgrid blockchain. Two aspects are taken into account: power generation periods and energy storage schedules.

The main generating devices of the regional energy system are photovoltaic panels (pv) and wind turbines (wt). Conventional fuel generators are used as emergency power generation equipment. The electrical energy exchanged between microgrids comes from electrical reserves, so it is not within the scope of the general model. An energy storage equipment mainly consists of lead-acid batteries.

The microgrid calculates its own cost of electricity generation and the cost of transactions with large power systems. On the basis of the calculations, an objective function is built to optimize the sale or purchase of capacities through the macrogrid blockchain.

The process of trading energy between microgrids under the blockchain is divided into separate stages. The selling price of electricity in a large grid does not change with time, but the price of electricity in transactions between microgrids changes over time. Transaction participants naturally prefer to trade with microgrids with lower rates. To achieve more efficient electricity trading, it is necessary to develop a dynamic method of managing the blockchain as a whole, which this technology allows to do very efficiently.

The mechanism of bilateral auctions should provide flexible allocation of resources, ensure the coordinated and orderly conduct of multilateral transactions, and is widely used in multilateral trading platforms. The bilateral auction mechanism has basically two forms: direct bilateral auction and centralized bidding. Centralized trading should focus on the quotes of all trading participants for a certain period of time, and after several operations, reload the information. This transaction model requires the execution of transactions within a fixed time, while it requires a relatively large amount of calculations that require the involvement of significant computing power.

The direct two-way auction mechanism is more suitable for transactions between microgrids. The process of two-sided auctions is oriented towards the starting price and sale price models. The main control center of the blockchain balances supply and demand. When the total amount of electricity, offered on the market, is lower than the demand for it, the selling price will be increased accordingly, and vice versa.

When trading between blockchain microgrids takes place, no third-party institution is expected to be involved as a transaction coordinator. Instead, a smart contract technology is proposed, basing on the use of a special computer program that runs on the blockchain. The algorithmization of the bilateral auctions and the smart contracts allows to ensure following the business logic and to eliminate the risk of interference by third-party attackers. It provides trust between the parties of the transaction by logging the actions: all key information about the transaction is recorded into the blockchain for its further confirmation. Based on the price forming model, a proper form of the transaction is developed, and a smart contract is drawn up.

The contract design involves segmenting the lifecycle of the blockchain microgrid for 24 periods (hours) per day and calculating supply / demand in each period. All surplus will be distributed among the microgrids according to their needs, and corresponding smart contracts will be formed. The participants, whose requests were not satisfied, will receive energy from one of the major power grids at a fixed price.

The preparation and implementation of the smart contracts consists of several stages, such as registering requests, publishing offers, buying and selling, checking results, and settling transactions. Registration of requests and publication of offers are used for formation of quotations. The functional implementation of the purchase and sale is the mechanism of bilateral auctions, which has been described above. The function of checking results involves using digital signatures and recording information about the transaction in the blockchain. The transaction settlement function tracks the transmission of electricity and its payment, after which the smart contract is deactivated.

Development of the architecture of the decentralized and intelligent technology of blockchain transactions increases the efficiency of using the microgrid power and ensures the openness, transparency and security of transactions. Future development in this area should mainly focus on blockchain sharding technology and improvement of the speed and efficiency of blockchain algorithms, minimizing the imbalance between electricity supply and demand.

5. Some national blockchain usage models

The history of the use of blockchain technology in the energy sector can be traced back to April 2016, when residents of Brooklyn, New York, USA tried to conduct transactions to buy/sell solar energy using the blockchain platform. Since then, the approach has been used to support increasingly complex transactions in an ever-increasing demand for secure energy supplies in an increasingly decentralized energy environment.

There are different opinions regarding the prospects of the development of blockchain platforms, but an analysis of existing solutions in the power industry has shown that about 12 blockchain projects are currently under development and at the implementation stages. In Europe, the bulk of projects are focused on renewable energy sources. The extraction of own natural energy resources in the EU is steadily declining, as well as production of electricity from them, but the producing renewable energy sources is growing, the share of which in some countries already exceeds 50% [23].

Today, Germany leads the European countries in terms of the number of smart grid projects, followed by Denmark [24]. However, such small state as Estonia with population of 1.3 million also is very interesting because of its progress in digitalization. Despite the small number of citizens and a modest area of the territory, Estonia is 100% equipped with smart electricity meters, and the government of the country is actively using digital technologies [25].

The Estonian energy market is being actively transformed based on the blockchain; this is being done by the European company WePower in cooperation with the Estonian backbone network operator (TSO) Eltring. At the first stage of the project, data on the production and consumption of electricity in Estonia for the year (24 TWh) were transferred to Ethereum, which proved the technical feasibility of transferring such a volume of real data to the blockchain. This data was then converted into 38,973,240,000 Smart Energy Tokens, where each token means a smart contract for the purchase and sale of 1 kWh of electricity. Tokens can be traded and cashed out on the local wholesale electricity market, which is achieved by linking contracts to grid data via the blockchain [26].

Caspar Kaarlep (WePower) believes that the blockchain will help to increase the share of renewable energy sources in energy consumption: the system will clearly fix the source of origin of each kilowatt-hour in the general energy network and give buyers a guarantee that they are purchasing wind energy, and not generated by thermal power plants.

Let us note participation of China in financing the project on introduction blockchain technology to the Estonian power industry. In general, China belongs to one of the leading roles in practical implementation of this technology, which is facilitated by the quite centralized management of economy development, practiced in this country.

China set up the world's first energy blockchain lab in Beijing on May 15, 2016 [27]. Blockchain development has received the status of a self-regulating industry initiative, and blockchain development cooperatives have been opened. The State Electric Grid Corporation became the leader in the implementation of the technology. In November 2017, it submitted a patent application titled "Principles and Methods of Energy Management on Blockchain". The patent describes the structure of the blockchain, which consists of information blocks distributed among the nodes in order to avoid leakage of information, which is possible when it is stored centrally. The information in each block is stored in a binary tree structure, with each data change controlled at the root node of the tree. Through a simple check, the root node can detect that the data has been falsified. This patent indicated the direction of development of blockchain energy technologies in China.

The initial idea of the Chinese power system development was to improve the unified system of planning generation and supply of electricity. Indeed, centralized control reduces the cost of building and operating the power system, however, due to the uneven production of electricity, an imbalance in supply / demand occurs, and, in addition, transmission of electricity over long distances leads to large energy losses.

Since then, a lot of research has been carried out in the Chinese energy sector on the introduction of new network approaches. Distributed macro- and micronetworks, intelligent network agents for decision support, network monitoring systems, etc. were introduced. Not all the technologies have lived up to expectations, but there has been steady progress. Energy microgrids are already widely used, the concepts of the energy Internet and digital management of decentralized production, transmission, distribution and transactions of energy have been implemented. Most of the researches is devoted to the blockchain architecture of distributed energy consumption and optimization of power transmission.

One of the factors, stimulating the development of blockchain in the Chinese energy sector, is the intensive introduction of electric vehicles into operation. New energy vehicle sales in China totaled 1.367 million in 2020, up 13.3% year on year. New electric vehicle production in China was 1.366 million, an increase of 10% year on year, for a total of 4.92 million [28]. It is predicted that electric vehicles will account for more than two-thirds of global passenger car sales by 2040, rising from 3 million in 2020 to 66 million. With the growth of electric vehicles, the demand for charging equipment will inevitably increase. Many private charging stations can share chargers, set charging prices, and use blockchain for billing and payment.

The use of blockchain in energy is not limited to the electricity market in China. This technology is increasingly being used in other areas. Let us mention finance, IoS, logistics, public services, digital copyright, insurance business and social services. These areas cover, basically, all the most important aspects of the country life, so, many research institutions in China have taken up the development of blockchain technology in various aspects.

Currently, Russia is lagging behind Western countries and China in equipping smart electricity meters and deploying renewable energy sources. However, there is essential progress in the use of blockchain for settlements with consumers in the retail electricity market. Steps for the use of "smart" energy in Russia have been determined and a roadmap has been approved to eliminate administrative barriers to payments using blockchain technologies [29, 30].

The Russian electric power industry is a complex technological and economic system that includes more than 700 power plants operating at different levels (wholesale and retail markets), more than 1500 network organizations and millions of buyers (individuals and legal entities) consuming electricity according to different schedules. The functioning of the system requires prompt collection and analysis of a huge amount of information, timely adoption of managerial decisions, economic balancing the system, using collected experience and current data. Digitization of the industry is in progress, and software tools, needed for reliable storage and processing of large amounts of data (big data, blockchain, smart documents and others), are designing and introducing.

The new technologies requires an appropriate infrastructure, the development of stationary and mobile services [31]. In particular, for the use of blockchain technology in the electricity market, a necessary condition is 100% equipping of consumers with "smart" metering devices, integrated into the IoT/M2M (Internet of things and machine-to-machine communications) system, which collects information from the metering devices.

Results of the Russian IoT/M2M market research, conducted by J'son & Partners Consulting LLC (JPC), showed that as of 2018, the number of IoT/M2M devices, connected to the Internet, exceeded 23 million units. The long-term forecast from JPC assumes an increase in the number of connected devices by 2023 to 42 million units [32]. At the same time, it is obvious that the Russian IoT /M2M market does not take into account the need for intelligent electric energy metering devices ("smart" meters) as Internet devices [33].

By 2018, the total fleet of electricity meters in the Russian Federation amounted to about 70 million units. Almost 8–9 million metering devices are needed annually to replace existing and install new meters at industrial production facilities, housing

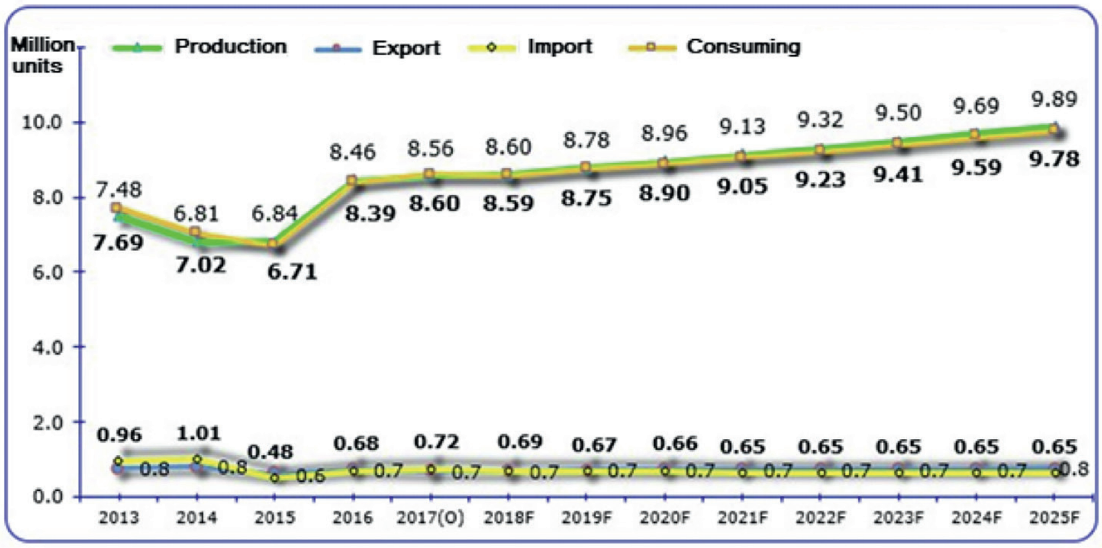

Figure 1.
Dynamics and structure of consumption of electricity meters in 2013–2017 and forecast until 2025 in million units (within the base development scenario).

and communal services, which is almost completely covered by domestic production [34] (**Figure 1**).

In 2018, the Federal Law No. 522-FZ "On Amendments to Certain Legislative Acts of the Russian Federation in Connection with the Development of Electricity (Power) Metering Systems in the Russian Federation" emphasizes that "the subjects of the electric power industry, consumers of electric energy (capacity) and other owners of electrical energy metering devices are obliged to carry out information exchange of data obtained in the course of providing commercial accounting of electrical energy (capacity) in retail markets and for the provision of utility services for electricity supply, necessary for mutual settlements for the supply of electrical energy and capacity, as well as for those associated with these supplies services, free of charge in the manner prescribed by the rules for the provision of utility services to owners and users of premises in apartment buildings and residential buildings, established in accordance with housing legislation, the rules for organizing electricity metering in retail markets" [35]. The norms of the Federal Law are aimed at unifying the various requirements for presenting a huge amount of information, a standard minimum set of functions for the intelligent electricity metering system, as well as the metering devices themselves.

The retail electricity market in the Russian Federation is represented by various participants: generating, grid, sales and management companies, settlement centers and ordinary consumers of electricity. Disagreements often arise between market participants: for example, between grid and sales companies on the volume of productive supply and the amount of electricity losses. Similar disagreements may arise between management companies and consumers due to the rather complex and non-transparent process of accruing volumes for general house needs (lighting entrances, operation of elevators, etc.). In addition, disagreements may arise due to different periods and methods of taking readings from metering devices. All this leads to disputes, often they are not resolved for a long time. The uncertainty of local data has a negative impact on financial calculations and, in general, on the energy market.

Large-scale work has begun in the Russian electric power industry to ensure transparency of payments and reduce non-payments, using the possibilities of digitalization. Thus, a group of companies PJSC "Rosseti" (Rosseti) is implementing a comprehensive digital transformation program, including the design and implementation of pilot projects to test the latest blockchain technologies [30].

A resident of Skolkovo, a company from Yekaterinburg "B41 Blockchain Development", developed by order of Rosseti an automated system for accounting and payment of electricity based on a completely domestic blockchain platform—Nodes Plus Blockchain. The project partner was Sberbank PJSC. The financial institution, acting as a payment bank, provided the server capacities of the SberCloud platform.

In 2019, the developer successfully tested a system for collecting information based on the blockchain platform and presented the results to Rosseti. The project included 12.5 thousand metering devices for electricity, cold and hot water on the basis of two residential complexes in Yekaterinburg [36].

The implementation of systems, based on blockchain technology, in the Russian power industry is focused on obtaining a number of benefits. Decentralization is assumed, when all network participants are directly involved in maintaining the system's performance, and there is not a dedicated center. Automatic distribution of data among its participants guarantees safety and immutability of the information, entered into the blockchain. Transaction transparency is ensured; all participants have access to the entire history of their transactions, up to the very first one. The speed of transactions increases, since they occur directly between users, regardless of their location and without involvement of intermediaries. Additionally, the absence of intermediaries reduces transaction costs.

6. Problems and risks

Naturally, there are some problems and limitations, associated with the use of the blockchain. One of them is the limited memory of the blockchain; for example, the memory size of the Bitcoin blockchain in mid-June 2018 was 171 GB. Another matter is a decrease or even lack of confidentiality, because each network user has a wallet address, assigned personally to him or her, and all network members can trace, what transactions were made from it.

In some cases, the use of blockchain is associated with significant energy consumption. Thus, according to a number of data, by the end of 2018, the Bitcoin mining took about 0.5% of the total energy consumption of the entire planet. In addition, one more weakness is the possibility of significant delays in confirming transactions due to problems with mempools (queues of transactions waiting for confirmation by miners in the network) [37].

At the technical level, breakthroughs are needed. The problem of network bandwidth is acute, since the blockchain copies all the information generated earlier into new blocks, so the amount of information in the next block is greater than in the previous one. Potentially, the amount of information in the blockchain tends to infinity, and eventually this problem will have to be solved once by revising the blockchain model.

One of the advantages of the blockchain—its consistent decentralization, creates certain difficulties. Decentralization hinders government oversight and, in many countries, it hinders the development of technology. Regulatory (in particular, fiscal) authorities should recognize the technology. To win their trust, it is necessary to make some efforts, both technological and in PR.

Blockchain transactions, like all commercial transactions, are associated with certain risks, and they have a number of significant features in this special case. These features of risks should be taken into account, when a business, related to the use of blockchain, is insured. In order to pay the insurance indemnity, the insurance company requires data, confirming the insured event, and checks the accuracy of this information. The big data and blockchain technologies should provide such possibility; corresponding data should be recorded, protected from falsification, stored indefinitely, and available to the insurer.

These properties, if it they reliably ensured, create new opportunities for the insurance business. Insurance information can be recorded on the blockchain, providing technical opportunity for data exchange between insurance companies that have joined the blockchain. Such data as customer's insurance history, claims records, etc. allows to assess better the level of risk for a particular customer. The exchange of information can be organized more widely, for example, between insurance companies and hospitals to prevent health insurance fraud. The use of network technologies creates opportunities for more accurate insurance analytics, which facilitates the creation and maintenance of insurance contracts.

7. Conclusion

The article discusses the main possibilities of using blockchain technology in the energy sector and proposes a general scheme of blockchain networks for information support of the energy market (primarily, the electricity market). One of the main functions of the blockchain is to ensure the trust of market participants in each other, due to the clear recording of all actions, the security of information and the transparency for participants of transactions [38]. Market actors have a high degree of autonomy in purchases and sales. The technology provides services for the preparation and issuance of invoices, as well as the organization of settlements for the entire transaction. It ensures the economic and information security of the participants in the transaction, as well as the efficiency of its implementation. Weaknesses and risks, associated with the use of blockchain in the economy, are analyzed and ways to overcome them are discussed.

Like any technology, blockchain is constantly evolving. Further research can be carried out in several directions [12].

Among the algorithms included in the blockchain, the consensus protocol, which is used to coordinate operations between individual nodes in distributed systems, is in particular need of further development. This is a key technology in the blockchain, which should be in line with the requirements of reliability (tolerance to failures and malicious attacks) and efficiency (high speed of convergence, that is, the speed at which the system reaches consistency or "steady state" [39]). The biggest challenge in implementing consensus agreements is to ensure a balance between safety and efficiency; currently, the speed of consensus algorithms (when organizing complex transactions) needs to be improved.

The underperformance of blockchain networks, in course of growing, is another serious problem. One solution is to use increasingly modern high-performance computers. However, an even more significant factor is the use of special intelligent software tools. According to the OpenAl survey, due to introducing and sequential training of artificial intelligence systems, the real computing power of computer networks has been growing exponentially since 2012, and the data processing speed has doubled every 3.5 months (much faster compared to Moore's law for processors, according to where the speed of computing doubles every 18 months). A convenient tool that goes well with blockchain technology is the intelligent the blockchain technology is an intelligent self-learning network agent—an avatar [7, 17], which automatically, during periods of low network congestion, processes data from the blockchain and generates proposals for concluding transactions.

Also, to improve performance, work is underway to improve network protocols, specially "sharpened" for the blockchain architecture.

The third problem, the optimal solution of which should be obtained in the course of further development of the technology, is to ensure the dynamic structural flexibility of blockchain networks. Three main models are currently in use: public, corporate, and private networks. The public chain is open to all users, the corporate chain serves a specific alliance of users, and the private chain is used by only one legal entity. Different blockchain products are being developed for the different models. At the same time, there is a great need to provide support both inter-network interaction and changing the model of a particular network: its decentralization in the transition to a public model, or centralization in the opposite case.

Business interactions between different organizations (i.e. interactions between different chains) can be a big problem. Accordingly, "cross-chain technologies" are currently being developed to solve this problem, and it is one of the main directions of blockchain development nowadays. The collected experience shows that, apparently, it is impossible to solve the problem without elements of centralization in the issue of harmonizing protocols between blockchains. Either generally recognized (on state or corporate level) standards of blockchain input/output interfaces are needed, or universal state-supported networks should be designed to provide a friendly information environment for interaction between separate blockchains.

An example is the HKTFP network, maintained by the Hong Kong Monetary Authority. The advantage of the model is that the public platform allows to objectively resolve information conflicts between blockchains, and also supports both a simple user registration and a system of basic business scenarios. It is important that such an environment helps to solve the above-mentioned problem of interaction blockchains with fiscal and other central authorities.

Finally, the blockchain management mechanism should be improved; there are all prerequisites for this. The blockchain contains the necessary logic to automate the voting process (concerning updating network rules, changing protocols, distributing quotas, determining the operator of the blockchain supernode, etc.). The standard model is the "chain voting", but its details vary considerably across networks, and this, again, makes difficult the inter-networking coordination. Significant work remains to be done to develop a detailed and most effective standard.

In the development of technologies for efficient and reliable data storage, the quantum model can become the main competitor of the blockchain technology. However, its future is largely connected with the success of the widespread introduction of quantum computing tools. With the existing models of computer devices, the blockchain is still out of competition, so we can expect new successes in the development of this technology.

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