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doi:10.15199/48.2021.12.32

Possibilities of using blockchain technology in the area of electricity trade settlements

Abstract**:** *The article describes the advantages and possibilities of using blockchain in various areas and sectors of the economy related to electricity trade and trading. The aim of the article is to present the components of blockchain technology that can be used in the settlement of the energy trade process, and to discuss the use of solutions based on blockchain technology that can be used in the electromobility sector and the production of energy from distributed sources. Based on literature studies, the focus was on the implementation of solutions based on blockchain technology in the process of billing electric vehicle charging and billing energy in the areas of energy clusters. The paper also specifies forecasts for the further development of the use of blockchain, electromobility and photovoltaic synergies.*

Streszczenie: *W artykule opisano zalety oraz możliwości zastosowania blockchain w różnych obszarach i sektorach gospodarki związanej z handlem i obrotem energią elektryczną. Celem artykułu jest przedstawienie składowych elementów technologii blockchain możliwych do wykorzystania przy rozliczeniu procesu handlu energią, oraz omówienie użycia rozwiązań bazujących na technologii blockchain możliwych do wykorzystania w sektorze elektromobilności i produkcji energii ze źródeł rozproszonych. Opierając się na studiach literaturowych, skoncentrowano się na implementacji rozwiązań bazujących na technologii blockchain w procesie rozliczania ładowania pojazdów elektrycznych i rozliczanie energii w obszarach klastrów energii. W pracy określono również prognozy dalszego rozwoju wykorzystania synergii środowiska blockchain, elektromobilność i fotowoltaiki. (**Możliwości wykorzystania technologii blockchain w obszarze rozliczeń handlu energią elektryczną**)*

Keywords: electric vehicle, blockchain, blocjchain technology, photovoltaic, electromobility, development of electromobility, energy trade
Słowa kluczowe: samochód elektryczny, blockchain, technoogia blockchain, fotowoltaiki, elektromobilność, rozwój elektromobilności, handel energią

Introduction

Electricity is a commodity that is traded in a competitive energy market. Like any other commodity, electricity has to be produced, then sold and delivered to end users, i.e. individual customers, companies and institutions. Processes in the field of energy usually take place with the participation of network system operators and intermediaries who enable the satisfaction of electricity needs of entities interested in purchasing energy to be met, these processes involve thousands of people, computer systems, clearing platforms and banks. The article focuses on the possibility of using the blockchain environment in billing related to electricity. This is the architecture of storing information in a way that guarantees the invariability of historical data. Blockchain is a decentralized (no central management unit) and distributed database or transaction or event log that functions as a growing one-way list of records called blocks that have links to previous blocks created using cryptographic functions and timestamps. Architecture stores data (here: the amount of electricity, accounting entries) encoded with cryptographic algorithms [1], operating according to predetermined rules, i.e. smart contracts, i.e. a set of rules for the operation (protocol) of a given digital contract, its automatic verification (reaching a consensus), enforcing negotiations or legal documentation of its important events in accordance with the terms of the contract.

The combination of these two fields of science and technology, i.e. issues related to electricity and blockchain, creates the possibility of a new synergy between electrical engineering and IT industries. The connection of blockchain technology with works related to production, distribution, settlement, balancing and electricity flows are not only in the trends of global development, but also constitute a point of mutual support. Electricity management, readings of energy parameters, power values, effective values of voltage and intensity are terms related to the implementation of an effective policy of using electricity, and like many others, they are permanently inscribed in the essence of electromobility and the renewable energy market. Thus, it occupies such an important place in terms of development in the field of electrical engineering.

There are already many advantages and possibilities of using blockchain in various areas and sectors of the economy related to electricity trade and trading. Based on literature studies, the focus was on the implementation of solutions based on blockchain technology in the process of charging electric vehicles and defining forecasts for further development of the use of blockchain and electromobility synergies, as well as on the possibility of combining blockchain and the renewable energy sector (RES) on example of photovoltaics.

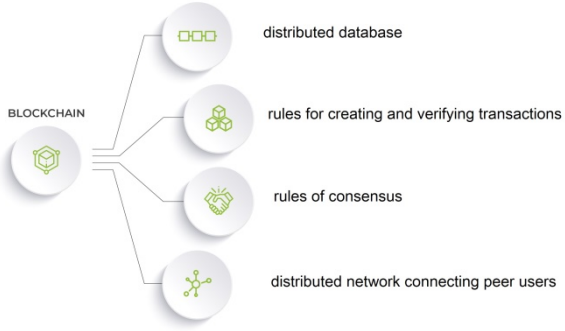


Fig.1. Selected blockchain functionalities

Electromobility and blockchain

Observing the electricity market and the growing market of electric vehicles (EV), you can see how great changes are taking place in them. The number of electric cars is growing every year, they are also getting cheaper and therefore more and more accessible to drivers (Fig. 1.). At the end of December 2020, the number of registered electric cars (the Polish market) is 18875 units. Out of the total number of EVs, 10041 were electric-powered cars (BEV, Battery Electric Vehicle), and 8834 were powered by plug-in hybrid electric vehicles (PHEV, Plug-in Hybrid Electric Vehicle). Comparing the two previous years, it is promising that the number of cars in 2018 has doubled compared to 2019 and increased by 140% compared to

2020. The market of charging points is also developing. More and more often, EV chargers can be found at petrol stations, shopping malls and cultural facilities (Fig. 2). While at the end of 2019, at the stations of the 16 largest charging networks, slightly more than 900 electric cars could use simultaneously, at the end of 2020 it was already more than 1500 (an increase by 65%). The plans of the 16 largest networks predict that in December 2021, more than 4200 electric cars will be able to connect to their chargers at the same time. According to these plans, the number of locations where the car can be recharged will increase from just over 600 at the end of 2020 to over 1800 by the end of 2021 [2] (Fig.2., Fig.3.).

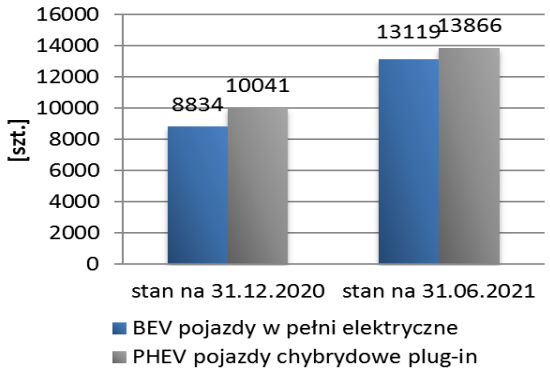


Fig.2. Increase in the number of electric vehicles in Poland [2]

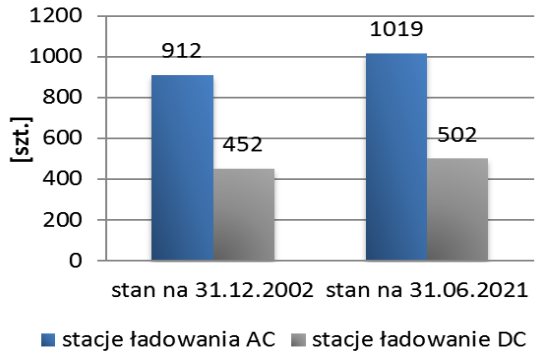


Fig.3. Charging points for electric vehicles in Poland [2]

It is in this sector of the market, i.e. electromobility, that blockchain sees the possibility of using its solutions with an advantage over the current standards. The certainty of the provisions is guaranteed by the aforementioned smart contract, i.e. computer code containing a set of business rules agreed by the parties concluding the contract, run on the blockchain. The smart contract is saved on the blockchaine, so it cannot be changed or canceled. When pre-agreed conditions are met, the contract is automatically and irrevocably performed. This mechanism involves digital assets and at least two parties to the transaction. This is exactly what happens during the charging process of an electric vehicle. When the vehicle is connected to the charger, the EV user, by agreeing to the charging conditions (including the energy price), initiates an intelligent contact. Usually, in addition to cash, payment for such a process also involves e.g. tokens, tokens related to the process and available on the market (or vouchers), which used in the process generate e.g. a reduction in the price of energy available in the charger. The entire process in terms of the flow of electricity, both to the EV user and to the charger in the power grid, is saved in blocks and billed according to the rules adopted in the contract. With the possibility of eliminating the central trust entity, each party has maximum certainty about the data and payment flows carried out in the process.

Such electric vehicle charging processes, taking place with the use of a charging station equipped with a billing system based on the operation of the smart contract idea, gains confidence in the correctness of the entire process and the possibility of saving it in terms of energy and finance in blocks. Such a record guarantees the invariability of data, transparency of the process and transparency of financial settlements, thus providing credibility of the record for both sides of the process.

When looking at the possibility of using blockchain in the area of electromobility, we are talking not only about the data of the charging process itself (i.e. the amount of electricity consumed, its technical parameters or finances), an important essence of blockchain is also the process called Initial Coin Offering (ICO). ICO is a method of raising capital by issuing cryptocurrencies or tokens in order to finance a venture. The entity organizing the collection (Investor) presents its plans and assumptions in a document called the White Paper, which is also a standard contract, and in return offers tokens that give appropriate rights in the form of, for example, priority to goods or services provided by the issuer, or allow investors to participate in profits from the project, or give voting rights to the entity entitled to the token. When talking about electromobility, a great idea to use this form of capital accumulation is the willingness to collect funds for the construction of EV charging points. This type of modeling is presented, among others in [3], which presents a mathematical model and assumptions for the idea of using blockchain to improve the pace of development of the electric vehicle and charging points market.

According to sources [4, 5, 6, 7], there are many possibilities to describe and develop blockchain technology and smart contracts. However, it should be remembered that they are a frequent topic of scientific discussions conducted by computer scientists. It is about the mechanisms of codes and algorithms, therefore, due to the dynamic nature of these applications, smart contracts must be much more flexible, responsive and controllable. The security aspect is discussed many times, which unfortunately has a negative impact on the development of smart contracts - that is why legislative issues are so important.

A work combining with the above-mentioned and at the same time having a common element of electricity trading is work [8] in which a model of local energy trading using the peer-to-peer (P2P) service among plug-in hybrid electric vehicles (PHEV) is proposed in smart networks. This model responds to the electricity grid demand by providing incentives for discharging PHEVs in order to balance local electricity demand. In addition, the work also deals with the security of such transactions. The numerical results based on an actual Texas map indicate that the dual-auction mechanism can achieve maximization of local-social welfare while protecting the privacy of PHEV vehicles.

The use of information recording in blockchain technology in the charging process is also a response to the growing popularity of electric vehicles and their alleged negative impact on the power grid. According to electricity companies and scientific sources [9], the growing popularity of electrification of private vehicles may have a significant impact on the operation of the system, especially on distribution networks, if the charging of electric vehicles (EV) is not properly managed. According to the source [10], blockchain can be used to manage the smart charging technique for EV. By using a fuzzy logic controller described as a smart contract, it is possible to manage the charging

process of an electric vehicle in such a way as to maximize the benefits for the electricity supplier and owner of the electric vehicle. The benefit for the utility company is to mitigate the impact of EV charging on the distribution grid by shifting EV charging to off-peak period, while the benefit for EV owners is low-cost EV charging, i.e. proper energy trading management. The controller regulates and controls the EV charging power depending on the electricity price signal provided by the energy company and the state of charge of the EV battery. Using the model of the described controller, it has been shown in the paper that the proposed method of intelligent charging reduces the impact of charging electric vehicles on the distribution network in comparison with uncontrolled charging.

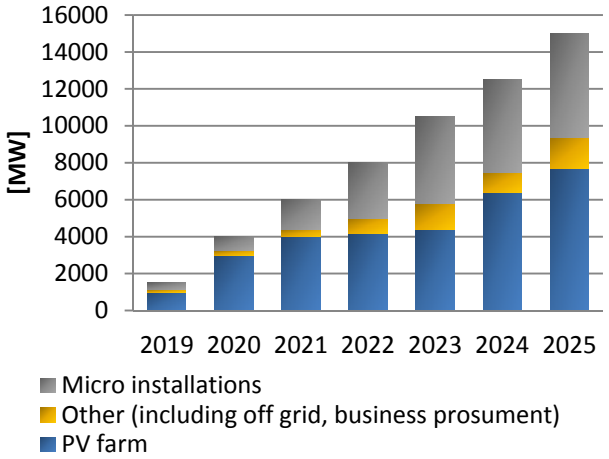
Citing the smart contract described in the above part of the article, it can be concluded that, at least in some cases, smart contracts may create binding rights and obligations for their parties. The mechanism best suited to describe the creation of a smart contract seems to be analogous to the vendor's machine, in which the declaration of will is clearly expressed in the performance of contractual obligations - it is in this context that the mechanism for selling electricity as part of EV charging is implemented. Smart contracts are an example of new types of technology-based contractual practices that companies and policymakers should start preparing well in advance. However, due to the relative immaturity of smart contract technology, the number of current real-world applications is still quite limited. The evolution of digital platforms requires an approach combined with technology, perspectives, economics and law.

Photovoltaics and blockchain

In the case described above, as in many other projects of this type, energy from renewable energy sources is used. Moreover, it can be seen that an increasingly important role in the decentralized energy market is trading in ever smaller amounts of energy. Domestic solar power plants account for about 80% installed capacity in Polish photovoltaics. At the end of July 2021, the photovoltaic photo power in Poland is robusta 5626,4MW. This means an increase of 210,6% compared to July 2020. During the whole of July 2021, the power of photovoltaic installations increased by almost 270MW. 30990 new PV installations were built, which is over 99% all RES installations built in July 2021. The average size of PV installations is 10,1 kW.

It is worth recalling that electricity has been supplemented (power plant) with RES with a share of 27,4 percent. (14,5 GW). The aforementioned renewable energy photovoltaics ranks second (after wind farms) with over 38%. at location [11].

So it can be seen that the Polish society willingly decide to opt for photovoltaics because it is ecological and allows savings in electricity costs, it can be seen from the development prospects (Fig.4.). Integrated with devices such as a heat pump, energy storage or an electric car charging station, it allows you to create a self-sufficient energy ecosystem that is friendly to the environment and the home budget. And that is why there is also a place for blockchain-based solutions here. The possibility of using smart contracts to conduct transparent and properly secured energy exchange transactions, precisely with the participation of the owners of photovoltaic installations (or home energy storage), becomes a new market for this type of synergy of both technologies. The benefits for the energy system and the operators managing it, in the case of IT solutions based on the idea of blockchain, are increased flexibility and network security. As we can see and as reported by the data, the energy system is becoming more and more dependent on variable generation, which creates a need for flexibility ensuring the right balance between energy demand and supply. Solutions in the form of applications based on blockchain solutions are the possibility of using the basic assumptions of such a system developed by the financial sector. We are talking about decentralized storage of data increasing security, making payments, concluding and verifying transactions, digitizing contracts, and the aforementioned lack of intermediaries in decentralized business models.



Fid.4. The perspective of the development of photovoltaic installations in Poland [12].

The first energy concerns, ie Vattenfall in the Netherlands, operators in the German market, as well as on the Polish market, such as Tauron and Energa and PGNiG, are already taking steps to launch this type of decentralized energy trade. Considering that the owners of the photovoltaic installation are small market participants with energy storage (electric car), the implementation of such projects and solutions in blockchain technology seems to be of key importance for the development and opportunities of combining these industries.

Energy clusters and blockchain

Continuing the synergy of the concepts of blockchain and electricity trading, it is also worth referring to energy clusters. Clusters are, in short, installations of renewable energy sources that will be or are owned by the community, they are accounted for among members of the community who decide how to carry out production and share revenues. From the very beginning, the concept of energy clusters, with the support of the Ministry of Energy, has aroused great interest and doubts as to its practical implementation. The most obvious are the methods of settlement, responsibility for network management, demand balancing, quality of supply, including network losses, downtime, voltage. Nevertheless, the combination of environments in this area shows that it is possible to use blockchain technology to provide a functional application layer for electricity trading and an information and marketing campaign, thus enabling the implementation of an energy cluster as an effective shareholder in the energy market [13]. The cooperation of energy and electromobility can also facilitate and make collective investments in photovoltaic installations mounted on buildings easier and more attractive. Their inhabitants (cluster) would be co-owners of these installations and they would be able to earn money by selling surplus electricity. The software used is to carry out transactions optimally, for example deciding whether it is more profitable to consume the energy produced at a given

moment, including charging an electric car or energy storage, or to sell it to the grid. This type of housing estate based on the idea of a cluster is to be built in the Australian city of Perth. The estate will consist of 10 blocks that are to be energy self-sufficient. This is to be made possible by a microgrid built especially for the needs of this investment, based on photovoltaic power plants and energy storage. In this way, the residents of the new housing estate are to use only locally produced renewable energy. Its surplus will be stored in energy storage, and a system based on transaction records in the blockchain technology will be responsible for the optimization of energy consumption, exchange and sale.

Conclusion

Blockchain technology is increasingly permeating everyday life. The fields of application of state-of-the-art technology range from banking to transaction hedging, mortgage tracking and commodity trading, ie energy. At the heart of the technology is a smart contract, which has the potential to revolutionize the way individuals and companies securely deal with each other.

When talking about the prediction of the development of blockchain technology, there are several main sectors and application areas in which blockchain is a place for gathering information. Accounting for the electric vehicle charging process and keeping a complete record of the transaction value are just some of the things to do. The charging process through the increasing number of EVs will effectively lead to new solutions in this field. By using a smart contract, i.e. a smart contract regulating all the conditions of the ongoing process, cryptocurrencies as a means of payment and a blockchain financial element, i.e. Initial Coin Offering (ICO) as a tool to obtain funds for the development and expansion of charging points, the use of blockchain becomes an alternative to the standard process of expansion of charging points and settlement of the EV charging process [4].

Anticipating the direction of development, it can be stated that instead of a clearly defined single use case, smart contracts and blockchain technology can be used in many cases related to energy trade, which are characterized by very different goals and circumstances, starting from the development of electromobility, the expansion of distributed sources installations and the creation of of them energy clusters.

Summarizing the possibilities of using blockchain in the electricity trading sector, there are several main application areas, including:

- settlement of utilities, i.e. electricity, gas, water, etc.,
- permanent information carrier,
- planning and control of energy supplies,
- electronic documentation of transactions,
- title deeds, theft prevention,
- counteracting "duplicated factoring" frauds,
- decentralized distribution of digital content,
- interbank payments and settlements,
- Robotic Process Automation (RPA)

Electricity as a product for the charging of electric vehicles is also a question about its source. The use of renewable energy sources for the charging process is another milestone for the development of distributed sources, and even greater for electromobility and blockchain, which, thanks to the essence of its operation, can effectively track all stages of the charging process using energy from renewable sources. Photovoltaics, which is so much in the increase in installed capacity, is ideally suited for cooperation with the charging process for EV, and with blockchain as a place for the settlement of the process. The use of electricity from solar radiation perfectly harmonizes with the EV charging process. This way of combining technologies gives the possibility to believe that it is in this direction that the development of the aforementioned technological and economic sectors should be looked for.

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