Use of Blockchain in Energy Trading

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In this article, we study the adoption of Blockchain technology in energy trading. We give a brief overview of the current state of electrical systems and exploring another approach that will respond to the new demands of society. Following this, we briefly detail the definition of Blockchain and its main characteristics, which constitute the main attraction for its inclusion in the electricity sector. Based on a meta-analysis, this study represents the current state of electrical systems, exposing the benefits and limitations that these systems have, and pointing to the main contributions that the use of Blockchain could bring. Challenges that Blockchain faces are also discussed. Finally, we present the conclusions of our work...

Keywords: Blockchain, Energy trading, Energy decentralization, Renewable energy, security, privacy protection.

I. Introduction

Blockchain technology, more than ten years after its appearance, has allowed various sectors to experience its possible advantages and innovative applications. The decentralization offered by such technology is in many cases its greatest attraction, in addition to its operation, preventing the data recorded in it from being manipulated, which guarantees transparent transactions.

In the electricity sector, certain motivations have guided in recent years the development of projects that merge the use of Blockchain technology with energy exchange, either between peers or more ambitious plans of companies that wish to create and commercialize their energy through decentralized platforms, which allow a transparent record of the origin, production, and distribution of energy independently of the companies that have historically maintained the monopoly of energy. The electricity sector has a complex operation that, for years, has been managed by small groups of companies that establish high costs for their services and have not sought other alternatives that benefit their users and reduce damage to the environment.

In this paper, we will study the architecture and operation of a Blockchain network to explain its attractiveness, and we will review current projects that have carried out the development of disruptive ideas when using Blockchain to improve or revolutionize the electricity sector.

The motivation of energy generation and exchange projects through a Blockchain seeks to promote the generation of solar and wind energy, among other green energy sources, in such a way that its producers consume what they require for themselves and can commercialize the surplus to a price that will be established by consensus within the network created for such purposes. Blockchain technology, in addition to offering small producers the alternative of monetizing power generation, can also introduce dynamism to the electricity sector and diversify the providers of such service.

We will also discuss the challenges that such technological implementations bring with them since large-scale scopes are difficult because they merit a large monetary investment and design of the architecture and operation to guarantee efficiency.

As a contribution, we will detail the security aspects that this technology must improve so that the implementations in the electricity sector guarantee the safe protection of user data and prevent third-party intrusions in the network.

II. Blockchain: Definition and Characteristics

Blockchain is defined as a structure that stores digital data, characterized by being shared, immutable, and distributed, forming a database that contains the record of transactions and the chronological order in which they are carried out. These transactions are aggregated into blocks that are registered on the network and are cryptographically related to the previous blocks forming a chain of records, these blocks are what form the Blockchain **Error! Reference source not found.**

According to **Error! Reference source not found.**, Blockchain has a series of characteristics, which are the key to the acceptance that this technology has, among them are:

1. Decentralization: This is the main characteristic of the Blockchain since its operation is independent of any central entity.
2. Immutability: The information stored in the blocks is unalterable, once registered and integrated within the blocks it will remain protected.
3. Anonymity: To carry out transactions between nodes of a network, only the address used by said nodes in the network is needed, which allows participation without revealing identification data.
4. Transparency: Based on the storage procedure of the Blockchain data, i.e. in chronological order and without being able to make modifications, it guarantees transparency.

5. Autonomy: The nodes participating in the network have access to all the registered information and can participate in it, respecting the conditions established by the consensus method used.
6. Open Source: Most of the projects developed in Blockchain leave their code available, which makes it possible to perform updates, vulnerability assessments, and offer improvements.

III. Electrical System: Operation and problems of the system

The electrical system and its development are linked to the economic advancement of society, given that access to electricity allows carrying out industrial, technological and social projects that are inevitably increasingly ambitious; this reality has shown that the existing system has certain shortcomings, which prevent meeting current demands. In many cases, to offer improvements in the service and to be able to cover operating and maintenance expenses of the system, increases are made in the prices of the service to invest in projects that optimize the system **Error! Reference source not found.**

According to researches [4] the existing electrical network, that is, the traditional one is characterized by being a rigid system that is inflexible in its operation, presenting limitations to generate, transmit and distribute energy to its users.

Besides, in current systems, all operations are managed centrally, which means that only a few companies control and govern the electrical system, making it not easy to adopt new alternatives for the generation and distribution of energy. This also means that its costs are established by a small sector.

On the other hand, the production of electrical energy has been causing an unfavorable impact on the environment [13] Companies dedicated to the generation and distribution of energy employ risk assessment strategies and seek to measure how their operation impacts the environment, however reducing such impact is not an easy task [19]

Currently, the electricity system in many countries is made up of centralized generation plants which are fed by hydro, gas or carbon, nuclear sources, among others that are interconnected by transmission and distribution systems, failing to cover a percentage important of the territory that depends on its operation, this has motivated the consideration of other forms of electricity generation whose impact is less on global warming, such as wind, sea, solar, biomass, geothermal energy [6] [9]

Ensuring the proper functioning of electrical systems requires work, investment, and organization on the part of the electricity service providers since these systems must remain in optimal conditions and up-to-date so that they can withstand the growing electricity consumption, this requirement is what maintains the variation in the cost of the service, a fact that can also cause people by themselves to reduce consumption, in the face of unannounced or disproportionate increases **Error! Reference source not found.**

All these aspects have led researchers to think of more optimal ways for the generation, storage, and distribution of electrical energy. An alternative, which we will explore in detail in the next sections, is that of the P2P *(pear-to-pear)* energy trading, particularly those in which Blockchain technology has been applied to regulate the exchange and interactions between peers.

IV. Use of Blockchain technology in the electricity sector

A trend in recent years has been to design projects that implement Blockchain technology in the electricity sector. These initiatives want to introduce the possibility that small producers of renewable energy can have a structured operation, independent of traditional producers.

These projects consider that the current advances obtained in the field of small-scale generation and electrical storage will introduce changes in the way in which energy generation and distribution have been managed in recent decades. One of these changes is being able to carry out P2P *(pear-to-pear)* exchanges, through a Blockchain, which in its design establish the rules of commercialization, benefiting the participating parties, according to **Error! Reference source not found.**

On the other hand, it is expected that the implementation of such technology can provide stable, reliable, and efficient production, transmission, and consumption of electrical energy, [26] since the electrical sector is constantly growing and every day presents new demands and challenges that the current system cannot face.

These ideas have been implemented by developers who have been interested in the potential of this technology, such is the case of the initiative proposed by **Error! Reference source not found.** whose work presents the design of a scenario for energy trading. They used the Multichain platform, which is a Blockchain characterized by being fast and scalable. In addition to this, to verify this scenario, they implemented a commercial system using Savoir, a JsonRPC module whose code is programmed in Python. This implementation yielded very good results, verifying that the creation of the Blockchain and the operation between the producer and consumer nodes is optimal, according to what is expected with Blockchain technology.

Another of the promises of the application of Blockchain in the energy sector is that it can contribute to the reduction of carbon emissions and reduce the cost of the service; these aspects were studied by [25] who specify that only small energy producers will participate in this type of initiative, that is, prosumers, who, in addition to producing it, have the option of marketing the surplus without needing intermediaries. Another the contribution of Tushar's work is that they made a study of the psychological aspects that can encourage the participation of small energy producers in such a way that the operation of the network is sustainable.

According to [18] it is a total innovation in the electricity sector, in which the term smart grid has been recently introduced, aiming to promote a more efficient way of distribution and generation of green and renewable energy. The authors affirm that the use of Blockchain can enhance smart grids in the electricity sector, given that it would add higher levels of trust, transparency, and security, in addition to being

the support for the idea of future smart grids decentralized, although there are limitations to developing this type of large-scale projects.

All these initiatives have arisen within the framework of technological innovation in recent years, with the adoption of electric vehicles for example, which are new energy consumers and that in a certain way promote or accelerate the evolution of the electricity sector. Electric vehicles require evaluating alternatives that allow them to be part of the development and not an obstacle in the operation of the novel smart cities [7]. By presenting the design of a Blockchain through which the interaction between its nodes can reliably handle the amount of energy required by an electric vehicle and sustain an autonomous mechanism, with its form of payment (cryptocurrencies), this proposal is presented as a secure energy trade.

On the other hand [28] consider that the growing adoption of electric vehicles has awakened initiatives that seek to meet the new energy demand, generated by the demand for massive battery charging. The authors propose that electric vehicles can be used as mobile energy storage with bi-directional charging and discharging functions to offer auxiliary services to the grid system, such as load flattening, reduction of spikes, and mitigation of frequency fluctuations, all this idea has been thought on a Blockchain.

Another utility that has been seen in the implementation of Blockchain for the exchange of energy is the design of the network can allow the monitoring of consumption efficiently, making adjustments, and minimizing any inappropriate use of energy within the network. This can also contribute to the early diagnosis of failures in the system, generating adequate maintenance, without neglecting the benefits of security and trust [3].

TABLE I. BENEFITS OF IMPLEMENTING BLOCKCHAIN FOR ENERGY TRADING

1. Eliminate intermediaries, reducing service costs and the rates are established transparently.	4. It reduces the risk of interruptions in the service since the network will not be able to overload its capacity.
2. Build trust by allowing automated peer interactions.	5. It offers the opportunity to small energy producers to participate dynamically in the exchange of their surplus energy.
3. Users can verify that they really pay for what they consume.	6. Promotes the generation of renewable energy

Table 1 summarizes the benefits of implementing Blockchain in the energy sector.

The innovation within the electricity sector gives rise to the exchange of energy on a small scale and promotes conscious consumption, this also has had to address legal aspects, such as how the correct operation of a Blockchain network should be from a legal point of view. This aspect is analyzed by [15] who propose the creation of a regulatory framework that establishes the regulations for the legal operation of the network, the article examines how the operation of a smart contract is, discussed how an inappropriate application of it puts consumer rights at risk, being vulnerable to price manipulation, violation of privacy, among other aspects.

Other authors highlight that the P2P energy exchange using Blockchain empowers small producers, allowing them to have an active role in the energy market with the development of collaborative energy projects, and present possible solutions or alternatives to continue growing in the development of projects that present viable commercial alternatives for energy supply [2].

In summary, the most relevant use cases where Blockchain has been applied to energy trading can be found in the Fig 1.

There have been several companies that have dedicated their effort to develop projects related to energy trading. In Table 2, a list of the successful companies in this sector up to date is provided. Most of these companies are innovators in cutting-edge technologies. They integrate into their developments not only the Blockchain but also artificial intelligence algorithms, Machine Learning, among other technologies. They also care about the environment, which is why they are also motivated by a concern for the environment.

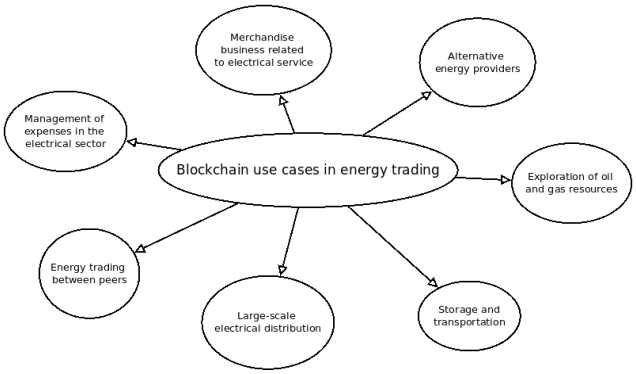

Fig. 1. Blockchain use cases in energy trading

TABLE II. MAIN COMPANIES AND PIONEER PROJECTS IN THE USE OF BLOCKCHAIN FOR ENERGY TRADING

1. Peer-to-Peer	Ponton, LO3 Energy, Power Ledger, Grid+, Energo Labs, OneUp. Volt Markets. Energy21 & Ponton, LO3 Energy, Power Ledger, Grid+, Energo Labs, OneUp. Volt Markets. Energy21 &Stedin ToBlockchain, Conjule. Greeneum, WePower, PowerPeers. Verv by Green, Running LTD, Energy Bazaar, Dajie, Oursolargrid, SunContract, Pylon Network, too much.energy, Divvi. OmegaGrid Solar Bankers. BP/Shell/Statoil
2. Utility-scale	Electron, Drift , TenneT/IBM/Vandebron/, Sonnen, Fortum, CGI & Eneco
3. Cryptocurrency	Spectral Energy, ElectriCChain/SolarChange/, SolarCoin, NRG Coin, Veridium, ImpactPPA Energi Token/Energi Mine, EcoCoin, Farad
4. Platform	Energy Web Foundation, Grid Singularity, Slock.it, Energy Blockchain Labs, BTL Group DAISEE, EnLedger, Prosume. DAO IPCI, Alastria, StromDAO
5. EV *(electrical vehicle)*	Oxygen Initiative, Share&Charge, Car eWallet, Everty
6. Other	The Sun Exchange, Bankymoon, Freeelio, M-PAYG, Poseidon, Clearwatts, Guardtime, WaveX, 4New Solar DAO, CarbonX, DNV GL/Deloitte, MyBit, BCDC (BlockChain Development Company)

V. SECURITY CHALLENGES OF BLOCKCHAIN TECHNOLOGY IN THE ELECTRICITY SECTOR

The implementation of Blockchain for the exchange of energy between peers has had great acceptance, but the existing proposals present certain vulnerabilities in security matters [10], for this reason, it is relevant to evaluate the problems and challenges to which this technology has faced so that its adoption provides stability and confidence to its users.

The design of the Blockchain architecture is evolving to meet the needs and demands that arise, its greatest strength is that it's based on cryptographic algorithms that guarantee high levels of security [27].

Being a novel technology and many of its implementations are not mature enough. Even though they are going through rigorous check processes, there are always potential loopholes that can be exploited.

Among these challenges are the need to improve efficiency, security, privacy, the method of data transmission for monitoring, sending instructions, and safeguarding them, automated billing of energy consumption, among others [8][14].

Reference [11] has addressed a solution that guarantees the security of the information stored in a Blockchain network destined for energy trading. Without restricting its commercial functions, the authors point out that it is important to guarantee the secure protection of these data since the network can suffer attacks that expose the geographical location of the users, as well as the pattern of their consumption. The proposal made in this work proved to be effective in the proposed context.

Tamper-proof attribute and transparency that public blockchain solutions, such as cryptocurrencies, have can lead to privacy issues. Once data is written on these types of blockchains, it can't be deleted or removed. With new compliance regulations, such as GDPR, writing someone's name is strictly considered a rule breaker

On the other hand, [17] argues that the use of smart contracts makes it easier to implement distributed energy exchanges and monetization. The authors point out that this fact can favor the reduction of transactive energy costs and increase the security and maintenance of the integration of distributed energy resources, and additionally eliminates the obstacles to establish a decentralized, resistant, and safe electrical network.

Other initiatives have proposed solutions for user authentication and anonymity within the network. In the field of electric cars, [12] have designed a hierarchical authentication mechanism using Blockchain, this proposal was widely accepted since it verifies the validity of its security against different attack scenarios.

In the search to improve security aspects, [24] propose a system for P2P energy trading, guaranteeing the protection of data and transactions through the encryption of offers, for this, they use encrypted Smart Contracts. The system ensures that the information encoded in the encrypted offers is protected. The feasibility of the system was verified by implementing a prototype consisting of smart meters, a distribution system operator (DSO) server working on Ethereum.

Smart contract engines such as Ethereum enable end-users to write their code which is executed on the blockchain network. Similar power was given to the users by the invention of operating systems. Two things happened: 1. Users started exploiting security holes. 2. Incompetent users wrote bad software solutions. A similar thing is happening to the blockchain where the first thing is solved out of the box and the second one has already happened and is happening with consequences

As we can see, the research in security and privacy for the Blockchain Energy Trading area is in its earlier stages. It will need a constant review for not exposing the private data of the users and general security concerns.

VI. CONCLUSION

The exchange of energy between peers is understood as the trade of energy between people or association of people, where the production and marketing it are independent of intermediaries, this initiative is considered a part of the solution to the problems faced by monopolies that have managed the generation and distribution of energy historically.

The implementation of Blockchain technology in this area is a novel alternative in the creation of small networks for the exchange of energy, which has great acceptance since it offers benefits such as speed and transparency in transactions between peers.

However, such adoption is at an early stage and must overcome challenges that allow it to guarantee tangible improvements in the electricity sector, such as safeguarding user data, preventing service interruptions, reducing costs, among others.

Finally, it is necessary to consider that Blockchain technology is constantly changing and updating, so any energy exchange project that rests on its bases must be periodically reviewed to make the pertinent adjustments and guarantee its operability.

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