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Blockchain and electric energy transactions: a systematic review

Blockchain y las transacciones de energía eléctrica: una revisión de literatura

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Abstract: Blockchain, a data structure that securely and efficiently records transactions, plays a fundamental role in the creation of decentralized platforms. This emerging technology is transforming the energy transaction landscape, improving the efficiency, reliability, and sustainability of energy systems. In this study, a Systematic Literature Review (SLR) focused on the technologies employed in electricity transactions was conducted. Specialized databases such as Scopus, IEEE, ACM, and Google Scholar were consulted. The crucial role of Blockchain technology is highlighted, which is being widely adopted due to its focus on decentralization and its ability to establish immutable and transparent records. Various fundamental elements in these operations were identified, such as nodes, smart contracts, and optimization algorithms, which enable the effective and decentralized operation of the network, ensuring the security and reliability of transactions.

Keywords: *Blockchain, Systematic Literature Review, Energy Transaction, Technology*.

Resumen: Blockchain, una estructura de datos que registra transacciones de manera segura y eficiente destaca el papel fundamental en la creación de plataformas descentralizadas. Esta tecnología emergente está transformando el panorama de la transacción de energía, mejorando la eficiencia, la fiabilidad y la sostenibilidad de los sistemas energéticos. En este estudio se llevó a cabo una Revisión Sistemática de la Literatura (RSL) centrada en las tecnologías empleadas en las transacciones de energía eléctrica. Se consultaron bases de datos especializadas, como Scopus, IEEE, ACM y Google Scholar. Se resalta el papel crucial de la tecnología Blockchain, la cual está siendo ampliamente adoptada gracias a su enfoque en la descentralización y su habilidad para establecer registros inalterables y transparentes. Se detectaron diversos elementos fundamentales en estas operaciones, tales como nodos, contratos inteligentes y algoritmos de optimización, que posibilitan el funcionamiento eficaz y descentralizado de la red, asegurando la seguridad y confiabilidad de las transacciones.

Palabras clave: Blockchain, Revisión sistemática de la literatura, Transacción de energía, Tecnología.

1. INTRODUCTION

The energy supply, vital in our current society, has relied on sources such as fossil fuels, which, due to their high demand, are subject to eventual depletion due to their high consumption. Traditionally, we have relied on a centralized energy transaction model involving a unidirectional energy flow from the generation network to consumers. Furthermore, its structure entails excessive costs and adapts new generation sources difficult. This conventional infrastructure creates distrust in the adoption of renewable energy and the participation of small local producers since uncertainty in the integrity and security of energy transactions discourages the transition towards more sustainable and decentralized sources.

The systematic literature review allowed us to identify the most used technologies in the transaction of electrical energy, with Blockchain technology being the most prominent. This technology offers advantages such as decentralization, traceability, and transaction security, positioning it as an optimal tool for ensuring efficiency and transparency in this field.

The results of this review also reveal various components used in energy transactions, such as nodes, smart contracts, and optimization algorithms. These components allow the efficient and decentralized operation of the network, guaranteeing the security and reliability of transactions.

The review follows this structure: the methodology is detailed in Section 2; the results are presented in Section 3; the discussion takes place in Section 4; and the conclusions are presented in Section 5. Finally, references are included.

2. METHODOLOGY

To carry out this RSL is adapted from the methodological strategy for elaborating conceptual syntheses in software engineering proposed by Zapata and Barón [1] based on the systematic literature review process of Kitchenham and Charters [2]. Below, the phases and activities of this adapted methodological strategy are detailed (see Fig. 1).

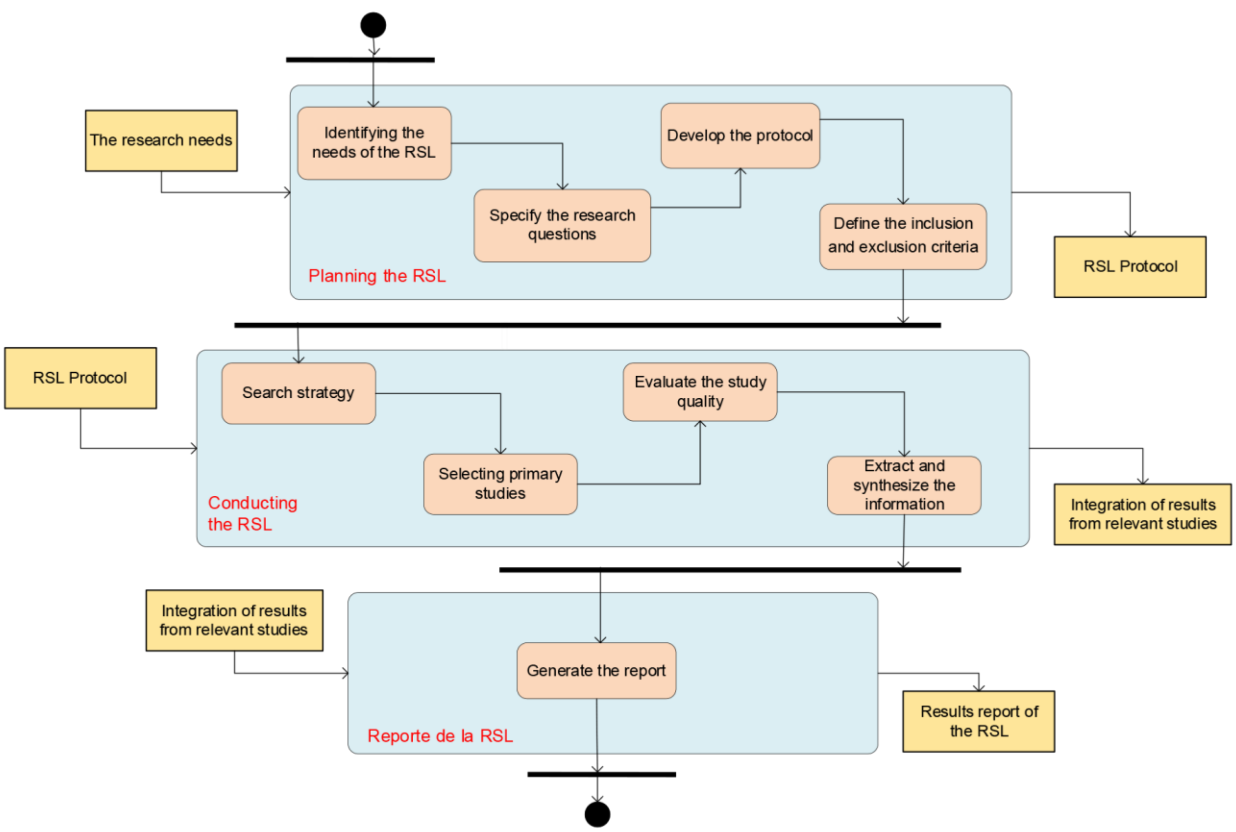

Fig. 1. *RSL process adapted for this research*
Source: *adapted from [1].*

2.1. Phase 1: RSL Planning

2.1.1. Identify the needs of the RSL

According to Kitchenham and Brereton [3]. The reason for conducting a systematic literature review arises from researchers' demand to comprehensively and impartially synthesize all available information on a specific topic.

Conducting an RSL on the technologies applied for electrical energy transactions makes it possible to identify, analyze, and compile the relevant literature related to this topic. These results will serve as a valid foundation to share with the scientific community.

2.1.2. Specify research questions

In the process of conducting an RSL, the formulation of research questions stands out as a crucial task. These questions serve to guide the primary study search activities, as well as the extraction and synthesis of the information required to address these questions [4].

For this RSL, two research questions, which are listed below

RQ1. What information/computing technologies are applied for electrical energy transactions?

RQ2. What are the components used in electrical energy transactions?

2.1.3. Develop the protocol

According to Kitchenham and Charters, the protocol must specify the methods, techniques, and tools that guarantee an exhaustive and impartial systematic literature review. To develop this RSL, the following are used: (i) identification of relevant and sufficient study sources for the research; (ii) the development of search strings to identify potential studies to be included in the analysis; (iii) the definition of inclusion and exclusion criteria to discern relevant studies for the research.

2.1.4. Define inclusion and exclusion criteria

The main purpose of inclusion criteria is to select relevant literature for the research; in this sense, the criteria for this review are shown in Table 1

Table 1: *Inclusion and exclusion criteria*

INCLUSION CRITERIA
Time window (2019 – 2023)
Studies that refer to technologies applied in electrical energy transactions
Title of the document related to electric energy technologies or transactions
EXCLUSION CRITERIA
Research in a language other than English is not considered.
Duplicate articles
Literature reviews or mappings are not considered.

Source: *The authors*

2.2. Conducting the RSL

2.2.1. Search strategy

The protocol establishes the use of search strings for this research. For the RSL on technologies that are applied for energy transactions, it is as follows: ("computer technology" OR "information technology") AND (“energy trading” OR “energy transaction” OR “energy exchange”).

2.2.2. Select primary studies

The objective of this activity is to select the truly relevant studies that contribute to answering the research questions [2].

• Identify study sources: The search for literature on technologies applied in electrical energy transactions uses digital sources, such as Scopus, ACM Digital Library, IEEE Xplore Digital Library, and Google Scholar (see Fig. 2).

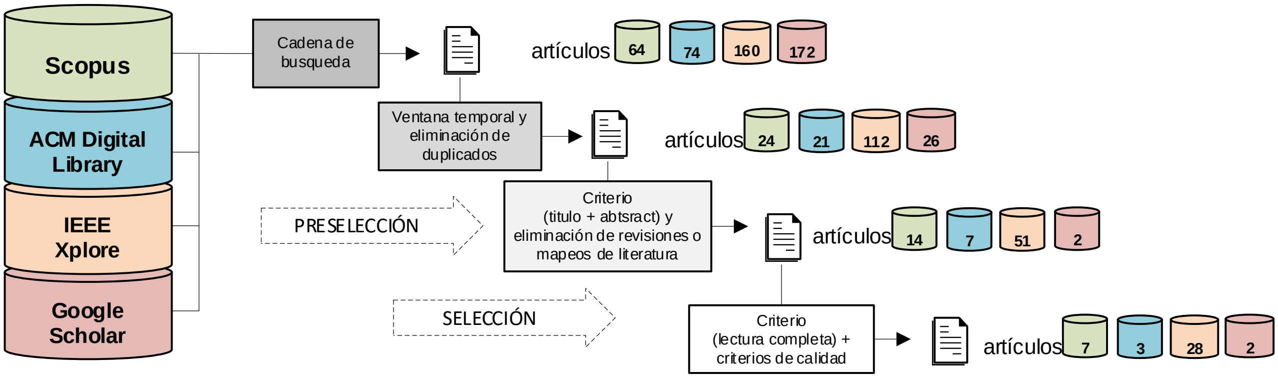

***Fig. 2.** Results study sources*
Source: adapted from [5].

• Select the studies: using the search string defined in activity 2.1 in the four previously chosen bibliographic sources, a set of 470 potentially relevant bibliographic records was obtained. After purging duplicates and considering the period between 2019 and 2023, 183 records remained. Titles and abstracts were then examined to identify those dealing with models and technologies applied for electric power transactions, highlighting seventy-four records for a comprehensive review.

2.2.3. Evaluate the quality of the study

The selected documents are evaluated using four criteria to ensure their quality: relevance of the content in addressing the key questions of the review, clarity in the research objectives, an adequate description of the context of the study, and clear presentation of the results. These criteria address three essential aspects of quality: the minimum level of quality, credibility, and relevance [6].

After thoroughly examining the seventy-four complete records, forty documents that met the established criteria were selected as fundamental sources for the systematic review.

These documents are presented in Table 2 and their bibliographic references, ordered chronologically by year of publication..

***Table 2:** Documents evaluated.*

Year	No	Reference
2019	8	[7], [8], [9], [10], [11], [12], [4], [13]
2020	15	[14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28]
2021	9	[29], [30], [31], [32], [33], [34], [35], [36], [37]
2022	5	[38], [39], [40], [41], [42]
2023	3	[43], [44], [45]

***Source:** The authors*

2.2.4. Data extraction and synthesis of results

The final phase of the process was oriented towards the extraction of relevant information, on the technologies applied in electrical energy transactions and the components used to such transactions.

Most of the articles focus on the application of Blockchain technology for electrical energy transactions in a decentralized network. Furthermore, they highlight the specific components used in these energy transactions (Fig. 3 and Fig. 4).

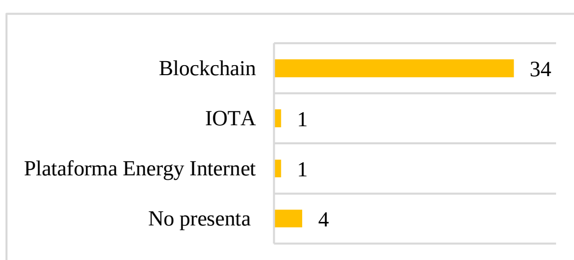

***Fig. 3**. Technologies for the transaction of electrical energy*
***Source:** The authors*

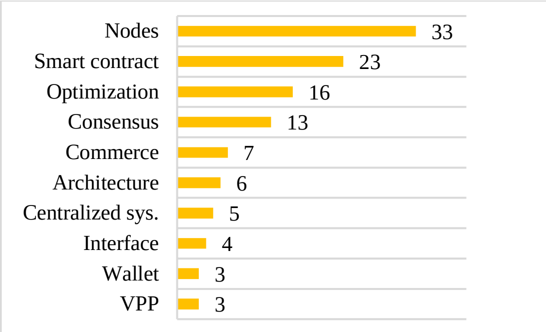

***Fig. 4**. Components*
***Source:** The authors*

2.3. Phase 3 RSL Reporting

The final phase of a systematic review consists of writing up the results of the review and disseminating the results to the interested community [2].

2.3.1. Activity 3.1: Make the report.

An analysis was conducted on the various technologies applied in electrical energy transactions was conducted, of which Blockchain technology is the most used. Likewise, the components used in these transaction processes were considered.

Within the identified studies, it was observed that 85% of them use Blockchain technology. This choice is due to its focus on a decentralized system, which makes it possible to create immutable and transparent records for all transactions linked to the exchange of electrical energy.

It is highlighted that 82.5% of the studies use the nodes component as a connection point in the network to share resources with other nodes within it. The nodes allow decentralized and scalable network operation, promoting user autonomy and resistance to failures because no central server coordinates operations. 57.5% of the studies use the smart contracts component as a tool to facilitate the electrical energy transaction between the network nodes. This is due to its ability to automate and decentralize the transaction process and provide transparent records that foster trust and ensure traceability in transaction operations. Furthermore, it can be observed that 40% of the studies use the optimization algorithm component that focuses on energy trading between network members. This implementation brings notable advantages in terms of operational efficiency and cost reduction, which results in greater profitability and competitiveness for those involved in the network.

3. DISCUSSION

This section answers the research questions established in the section corresponding to Activity 1.2 of Phase 1 of this review.

RQ1. In electricity transactions, technologies designed to optimize transaction efficiency and ensure their security are employed. The technology most used in this research is Blockchain, which stands out for its focus on the decentralization of the system, providing a series of advantages that transform how electrical energy transactions are carried out. This technology allows the establishment of unalterable and transparent records for all transactions. This quality is particularly beneficial as it ensures the traceability and authenticity of all data involved in transactions while drastically reducing the risk of improper manipulation of information. This technology, with its ability to create an impenetrable and publicly accessible logbook, represents a revolutionary innovation in the energy industry by decentralizing the system. Blockchain eliminates the need for a central authority to manage transactions, reducing the risks of manipulation or system failure. Each transaction is recorded in a block and securely linked to previous ones, forming an immutable and completely verifiable chain by all network participants.

RQ2. The electricity transaction requires a high degree of trust and security between participants in all phases of operations. Trust is essential to ensure that energy is delivered efficiently and reliably. In addition, security in operations is essential to ensure that transactions can be verified and stored transparently and without alterations. The components used in the electrical energy transaction stand out: the nodes that play a fundamental role by serving as crucial connection points in the network. These act as communication and coordination points between the various participants, facilitating information flow and ensuring operations synchronization. Consensus is responsible for verifying and ensuring the integrity of transactions. This mechanism guarantees that each energy transaction meets the established requirements, providing additional security to the process. Network participants must agree on the legitimacy of each transaction, which contributes to the trust and robustness of the system as a whole. Smart contracts, for their part, represent a key innovation in this equation. These self-executing programs automate and manage the terms and conditions of agreements between the parties involved in the energy transaction. By doing so, they facilitate a fluid exchange without intermediaries, which speeds up and simplifies the process for all parties involved.

These components work together to create a secure and decentralized network, ensuring that electricity transactions can be verified, recorded, and stored transparently, reliably, and immutably on modern networks. This means that electricity transactions can be verified, recorded, and stored in a transparent, reliable, and immutable way on modern networks, which ensures not only operational efficiency but also the integrity and traceability of each transaction that is conducted, being the foundation for a safer and more reliable energy future.

4. CONCLUSIONES

This research used a systematic literature review approach to collect, analyze, and summarize research advances related to the treated field. The process begins with the comprehensive analysis of seventy-four articles, of which, after a thorough examination, thirty-four are excluded because they did not fit the previously established inclusion, exclusion, and quality criteria. The remaining forty works make up the evidence base that allowed us to address the two questions of interest posed in the methodological strategy of this study.

After carefully analyzing the relevant studies, it has been possible to address the questions raised in this research. The findings reveal that Blockchain technology is a highly relevant and effective solution for electricity-related transactions.

The rigor of applying the methodological strategy allows us to guarantee that the results obtained are a valid foundation that can be shared with the scientific community.

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