Challenges Smart Grid in Blockchain Applications

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Abstract

Globally, interest in renewable energy has grown recently. The microgrid integrates traditional dispersed energy resources utilizing technological tools and information technology, making it more effective and flexible to enhance the economic and environmental situations (IT). One of these technologies that has drawn interest in microgrid applications to create a sustainable society is blockchain. The blockchain idea can offer immutability for microgrid transactions such as recording power generation levels and confirming transactions between generators and end consumers. By eliminating the need to connect with third parties, blockchain-based smart contracts can be utilized for auditing or resolving a transaction dispute between the producers and the users. In this paper, we highlight many recent research projects on blockchain applications in microgrids and the use of smart contracts to enhance the transactive resilience in microgrids.

Keywords*: Smart Grid, Blockchain, Cyber Security, Smart contract, Microgrid*

1. Introduction

Electricity has become the most frequently discussed topic in business today since it is used in so many industries, including the transportation and healthcare sectors. The centralized distributed energy plants that produce electricity have faced numerous economic and environmental problems over the past few years [1]. Therefore, it is necessary to develop a sustainable framework to address those issues and obstacles. By supplying optimal and dependable electricity, the use of microgrids enables the power system to operate more efficiently [2]. Because the smart grid concept incorporates a variety of contemporary technologies, including wireless sensor networks and the Internet of Things, it has recently been used to enhance the integration of various distributed energy resources and promote sustainability (IoT). Through information technology (IT) assistance between the main grid and the consumers, and vice versa, the dependence on smart grids promises more efficient use of renewable energy sources. The need for third parties to record and verify power transactions, even with the use of a smart grid, is a barrier to a reliable power network [3].

The implementation of blockchain technology presents a novel way to create a decentralized system that forbids interaction with third parties. Blockchain technology functions as a sharing ledger between network users to guard against transaction process manipulation. The Blockchain's architecture enables the creation of new blocks that can be used to store data continuously [4] . With this architecture, the smart grid is adaptable and redundant against errors and cyberattacks. Smart contract-based blockchains can work without human intervention to construct and record blocks of data that are more resistant to alteration and invulnerable to it. The blockchain's smart contracts function as long as all of the

established protocol's predetermined conditions and requirements are met. The contract typically runs in accordance with the preprogrammed structure and cannot be altered. Due to the emergence of local electricity markets and the need to increase the security and transparency of peer-to-peer (P2P) transactions, blockchain technology and smart contracts have recently attracted a lot of attention. As a result, by validating the necessary preset criteria of the transaction, the Transactive Energy (TE) by buying/selling power between the producers and users no longer required necessary processes from the bank. There aren't many evaluations in the literature about using smart contracts and the blockchain in the smart grid to handle security, privacy, and trust challenges [5].

The authors discussed the significance of the distributed energy system in microgrids and the detailed architectures of the decentralized system built on blockchain, including distributed ledger technology (DLT). Then, this analysis assessed the functional layers of the Brooklyn microgrid's transactive energy. highlighted the blockchain's primary use case and commercial deployment in the smart grid before addressing the block's precise structure and architecture classification [6]. The National Institute of Standards and Technology (NAST) conceptual model was used to assess the blockchain's suitability for use in smart grids and to characterize the decentralization of the blockchain. emphasized the use cases for blockchain, such as the idea and potential in the smart grid. This poll came to a few conclusions as well as different future aspects. offered a thorough investigation to provide the simplest instructions and citations of earlier studies that have been supporting the blockchain-based smart grid cybersecurity mechanism. The writers discussed the installation and advancement trends of blockchain in various energy internet and P2P situations, as well as its application and functional views. I looked at a number of academic articles on blockchain-based energy trading marketplaces that dealt with security and privacy, the auction pricing mechanism at the time of settlement, and how to improve the advantages of the smart grid. analyzed numerous initiatives using technical criteria such as the type of blockchain utilized, the hardware used, and the utilized or underlying blockchain [7].

Offered a thorough explanation of a blockchain-based P2P energy exchange infrastructure for the local energy market of the smart grid community. offered a comprehensive investigation and concept of the blockchain in P2P smart grids and suggested the actual importance of the study and the area's focus on development in light of a number of considerations, including social, economic, and environmental ones [8]. discussed the use of machine learning for creating blockchain-based smart grid applications, where it was discussed how to use both blockchain and machine learning to stop network threats. The purpose of this paper is to discuss the opportunities for blockchain research in the field of smart grids and to realize the state-of-the-art potential of blockchain technology in smart grid applications. This study also briefly discusses the difficulties and problems associated with the use of blockchain in smart grids. The essay is set up as follows. A description of the blockchain is provided in Section 2. A review of the smart grid's components is provided in Section 3. The blockchain's use in the smart grid is introduced in Section 4. Finally, discusses several research concerns and difficulties with the smart grid's use of blockchain technology [9].

2. Blockchain Overview

Due to its many important advantages, including transparency, decentralization, flexibility, and environmental effect, blockchain technology has recently attracted interest. As shown in Fig. 01, a blockchain is a decentralized ledger that connects other ledgers using the preceding block's hash address. These ledgers are keeping track of the many transactions carried out starting with the first block in the chain and disseminating the information to all current chain participants. Additionally, because the hash address changes with each repetition, the recording of ledgers can be protected from a cyberattack [10].
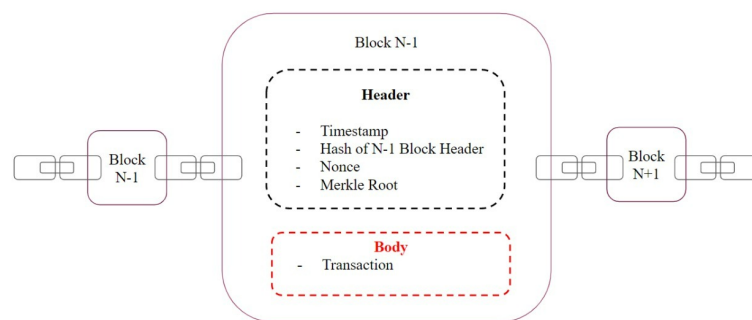
Fig. 1 Structure of the Blockchain Basic

A timestamp is the date and time when a block was created.The timestamp helps to determine the block's position in the main chain. On the table. 1, blockchains are divided into three categories [11].

Parameter	Public	Consortium	Private
Receptivity	Totally open	Semi open	Open to private users
Access to write	Any person	Specific user	Private users
Access to read	Any person	Any person	Open to the public
Obscurity More	More	Less	Less
Transaction speed	Low	High	Very High
Decentralization	Fully	Less	Very less

The earliest application of the blockchain concept was in the financial industries, where it was used in cryptocurrency transactions as the underlying technology of Bitcoin. The blockchain as we know it today has evolved over time by keeping the same principle but upgrading the body block format. The blockchain is capable of distinguishing between versions Blockchain 1.0, 2.0, 3.0, and 4.0. The most recent iteration of the blockchain, known as blockchain 4.0, is centered on sharing the ledger and the information in real-time [12]. This generation is typically integrated with industry applications via smart contracts, which do away with paper-based agreements. JavaScript, Python, Matlab, and other programming languages are used to build blockchain, but Solidity is the most popular one because it is made to work with the Ethereum Virtual Machine (EVM) [13]. The main benefit of blockchain is that it enables a group of entities to reach an understanding on a certain operation and record a contract without the need for a governing body. Using blockchain, the established activities are documented, secured, and shared with all stakeholders. Additionally, incorporates cryptographic and P2P network protocols to support a shared ledger spread among groups of blocks or users. The blockchain can be used in a variety of business industries. Any

information that shows a transfer of property between two or more parties, including the production of electricity, is a transaction [14].

2.1 Smart Grid

The smart grid is an improvement to the electrical grid that allows users to manage and regulate energy decisions using various IT devices, sensors, computing technologies, and cutting-edge communications while also optimizing energy production and bi-direction distribution. There are significant differences between the conventional power supply and the smart grid in the bi-directional commerce between the consumers and the main grid [15]. Through automatic remote metering, which enables consumers to store energy in energy storage devices during periods of low energy prices and sell energy during periods of rising power demand, the cost of production is decreased. Due to the transactive and transparent nature of the electrical market, which is typically monopolized by government agencies, precise energy metering is crucial during power exchanges [16]. These governmental bodies have greater faith in financial transactions. The smart grid can, however, be extremely vulnerable to cyberattacks due to the current communication architecture, which can also covertly contaminate field measurement data [17]. Therefore, it is necessary that the electricity trading be transparent via the blockchain in order for the entire information history to be rebuilt from prior registration in a reliable manner. The smart grid can incorporate a variety of technologies, including: Distributed energy resources include a combination of hydropower, wind power, and solar power and can be used to power a single or group of buildings, such as a home or an industrial facility [18]. By collaborating with renewable energy sources, distributed generation can aid in the delivery of a safe and dependable energy source. Equipment that stores energy in various forms, such as batteries and capacitors, are called energy storage devices. To provide a consistent power supply to the microgrids from standalone renewable power plants, the energy storage technology can be very important. Additionally, the energy storage system can store extra power generated by distributed energy sources when the supply of energy outpaces the need for it [19].

Power electronics: The output type of an energy generation system can impact the stability and dynamic functionality of a grid-interfaced system. Thus, to ensure stability under quickly changing grid conditions, must use a power electronic system, such as inverters and rectifiers on the transmission side. Communication technology and the Internet of Things: As was already said, smart grids, which are the key to connecting the power generation resources and metering/operation devices, rely heavily on communication technology (CT) and IoT devices. High resolution data can be gathered, recorded, and sent by CT and IoT devices to produce a set of operational decisions [20]. The ability to control and communicate with remote areas easily, a quick response time, wireless connectivity, decentralization, and high performance are some features of CT and IoT devices. As shown in Fig. 02, the IoT devices essentially have three layers: the perception layer, the network layer, and the application layer [21].
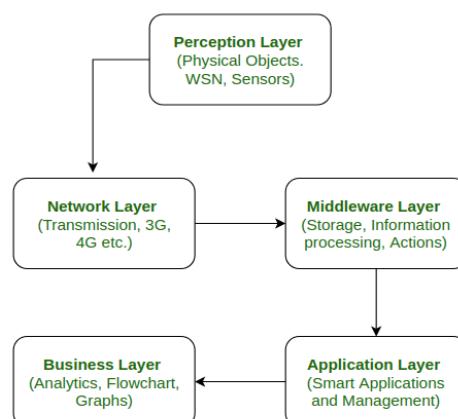
Fig.2 Internet of Things Architecture

2.2 Smart Contract

Szabo proposed the idea of smart contracts in the 1990s as a computing process that is permitted to meet certain criteria under specific circumstances. This idea is supported by the evidence of algorithm structure. Every transaction execution in the smart contract process has a unique address and smart contract code to maintain the security of the transaction for each customer taking part in the operation [22]. Then, with the verifiability of the trace being cryptographically verified, each participating client has the independence to independently review and freely inspect the code. A contract's code is set when it is created and cannot be altered after that point [23]. Because of their autonomy as a result, smart contracts benefit from computer operators. The smart contract is a soft script that is disseminated and recorded in the blockchain in a blockchain concept. It is self-executing and does not require a valid linking agreement with a third party [24]. Every energy transaction and activity is recorded in decentralized registries using smart contracts on the blockchain. Due to its autonomous and decentralized transaction structure, blockchain has the ability to record information on peer-to-peer transactions. If the blockchain is used in conjunction with a distribution system operator, this P2P system can lessen the downsides of IoT devices. The most well-liked systems for creating smart contracts are thought to be Ethereum and Java. On the Ethereum platform, smart contract authors are free to create any decentralized application they like. Decentralized code execution eliminates any possibility of oversight or fraud [25].

2.3 Blockchain In Smart Grid

The use of blockchain technology in the banking, law enforcement, and industrial sectors promotes its application to smart grids. Blockchain is regarded as the system in the power network with the most potential for safety and optimization. able to support the accuracy of transactive energy information from a safety perspective. Additionally, the capability of autonomously detecting missing data and operating instantly to change sensor infrastructure settings. Regarding the most current blockchain applications in the transactive energy market, earlier study categorized the qualities to meet the goals as shown in Fig. 3. Additional potential benefits of the blockchain may include the ability to simultaneously verify multiple distributed ledgers, reduce energy costs by omitting third parties, make operating a distributed energy system simpler, and motivate consumers to produce their own energy and exchange it with the main grid. Some of the viewpoints on integrating blockchain into the smart grid are presented in the section that follows.
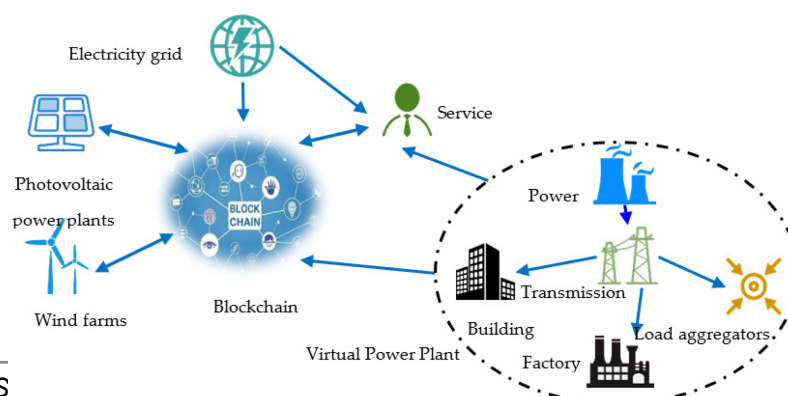
Fig. 3 The features of Blockchain in transactive energy

A. Decentralization of Smart Grid in Blockchain

The primary barrier in the conventional system is the centralized protocol, which makes it very difficult for individual operations and exposes the entire database's contents to loss in the event of a system assault. While the power is typically transmitted across a great distance to the end customers in energy transmission. Because the data of the producers and end users is registered in immutable blocks based on the smart contract, the usage of the decentralized platform can lower the attack ratio and minimize fraudulence. The goal of the shift from centralized to decentralized computing is to provide greater data integrity, scalability, and adaptability owing to resilience to failures.

Based on trading computer resources and P2P implementation between users and producers, the blockchain provides a decentralized platform for usage in the smart grid. Smart contracts govern those decentralized platforms in the smart grid. Different plans and architectures for implementing blockchain in the decentralization of the smart grid have been proposed in engineering literature. To guarantee the operating set of limitations and purchasing utilizing a decentralized smart grid, a thorough framework of P2P energy transactions has been suggested.The network of various distributed energy systems, including storage and load scheduling, operates at a decentralized optimal power flow. Without relying on outside parties, the energy management system optimizes the power distribution from each energy generation and securely stores it on the blockchain. This study proved that using the blockchain and smart contracts is reliable, secure, and transparent. In order to validate energy transactions on a decentralized smart grid market and get rid of third parties of entities, the authors created a smart contract.

The project has been put into practice in a number of university-campus agents that integrate with renewable energy sources and are built on the Ethereum blockchain. presented a blockchain-based decentralized privacy-preserving data aggregation (DPPDA) structure for a smart grid. The home smart grid's structure cryptosystem algorithm gathers the data from each smart meter. The system stores the data in the well-known SHA-256 format seen on the Bitcoin blockchain. presented the decentralization scheme of the data information sources from the smart meters and sensors, allowing the blockchain in the smart grid to guarantee the security of the transaction.

B. Smart Grid in Cyber Security Blockchain

The smart grid is susceptible to network-based cyberattacks, just as other cyber-physical systems. The vulnerability of smart grids to cybersecurity assaults includes IP address scanning, communication device hacking, visible pores, and soft virus attacks. These cyberattacks have the potential to corrupt measurement data, disrupt information outcomes, and deceive operations center judgments. As a result, there could be problems with the smart grid's operation and connectivity. The decentralized smart grid's consistency model and the blockchain provide important defense against security risks and hacking. The blockchain ensures many defenses against cyberattacks. In the event of a cyberattack, improving the cybersecurity of the entire smart grid is possible by changing the hash address throughout each repetition.

The use of blockchain cybersecurity in the smart grid has been divided into three categories based on prior studies: measurement and communications, power generation and transmission, and power distribution. The security of the smart grid has been explored toward security danger during the energy exchange, and a security scheme using the rainbow chain in blockchain has been presented. Utilized the directed acyclic graph (DAG) built into a decentralized blockchain for smart grid cybersecurity and security, eradicating energy

transaction fraud and lowering overall operating costs. created a framework for secure data transfer utilizing blockchain technology and addressed the possibilities for cybersecurity communication in photovoltaic (PV) system-integrated smart grid inverters. applied the idea of a worm computing model in decentralized blockchain to assure unchangeable ledgers in the chain, as well as cooperative defense and cybersecurity enhancement of the system.

C. Energy Trading in Blockchain

Customers and producers can sell locally produced renewable energy, the balance between power generation and demand in a decentralized smart grid, in local energy markets. Electricity buying and selling requests are communicated via a blockchain-based platform, and the demand is connected to real-time or closed times using the transparency. The advantages of implementing blockchain for trade-in smart grid include getting the best distribution, balancing the supply and demand of power, and having autonomous control. On the other hand, electricity bidding is dependent on predicting the time ahead of the power supply and demand load, which is obtained by a smart grid energy management system.The P2P energy idea supports small energy consumers and producers by encouraging self-production. Promoted and developed trade infrastructure is crucial for an efficient P2P trading process. That architecture must be reliable and safe. Blockchain technology has distinguished itself as practical and flexible for the use of a safe and successful decentralized trading market in the smart grid.

It presented a trading model to buy and sell the electricity generated by renewable resources and delivered by the smart grid. NRGcoin, a cryptocurrency that was also established, was intended to be used as the regional coin for transactions between producers and prosumers. The suggested decentralized blockchain can circumvent the third party by applying three smart contracts in the trading market, implemented as a P2P in the hybrid energy market. This study's major goal is to lower the electricity's peak to average ratio. created a blockchain algorithm for the smart grid using distributed coalition form. The outcomes of the experiments demonstrate that the created algorithm swiftly converges during the exchange of energy between consumers and producers. The P2P energy trading solution was built up using a Ciphertext Rules Attribute-Based Encryption (CP-ABE) topology to preserve local market policy and validate transactions transparently and autonomously without the addition of authority.

D. Smart Grid in Cyber Security Blockchain

In the networked trading market, every customer is regarded as both a consumer and a producer. Participants in network transactions must forecast demand for the transaction and the anticipated selling price for the upcoming time period before beginning the transaction. The deal can be finalized successfully if both the seller and the buyer agree. The double transaction method makes reference to multiple users who use the transaction as a means of exchanging information. presented a blockchain-based cyber-enhanced transactive microgrid model with an optimized users' authorisation mechanism to speed up transactions while providing convenience. The simulation proved that the size of the transaction block and the rate of information transfer are connected. The authors bridged the gap between limiting the total number of transactions applied in the blockchain and omitting the local transactions' confirmation by using the local peer network. According to the evaluation, the weight and size of the transferred ledger have significantly decreased. Using a smart contract built on the blockchain, the issue with the remote area's electrical network connection and transaction was resolved. With the use of the blockchain, it would be possible to arrange the selling and buying of electricity without a middleman.

3. Research Issues And Challenges

The key concerns and difficulties with the use of blockchain in the smart grid are outlined in this section.

- As blockchain technology is used on a broad scale, the size of the distributed ledger expands, increasing the amount of chain-related data that is needed. This deficiency may cause the process of mining the blockchain to take longer each time the hash address needs to be changed in order to save all the data. The advanced metering infrastructure and the blockchain mining facility's significant power usage could make it difficult for consumers and producers to come to an agreement on how to pay for this energy consumption.
- One significant issue that poses a threat to cybersecurity in smart grid applications is the scalability of the blockchain.
- The interval time, a very difficult problem in the blockchain application that requires time to process, is inextricably tied to the smart grid activities.
- In most cases, the sharing user's ledger employs pseudonyms addresses to carry out unidentified transactions, making these ledgers potentially untraceable and unidentifiable. The blockchain design plan for the smart grid must take into account a variety of network system requirements in order to guarantee efficiency and dependability.

4. Conclusion

The Blockchain technology utilized in smart grids has recently advanced, making it a ground-breaking technology, particularly in the dependable and secure framework for operations.In order to create an efficient and dependable system, this article emphasizes and examines several idea applications of blockchain in the smart grid, such as distributed ledger technology, P2P, trade, transactions, cybersecurity, and local energy markets. We started off by going through a thorough background of the blockchain. Second, we gave an introduction to the smart grid's technologies. The smart contract and its significance in the blockchain were then discussed. After then, we emphasized the blockchain's uses in the smart grid. Finally, we discussed various difficulties with blockchain applications in the smart grid. This publication aims to open up a wide range of opportunities for more study in this field.

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