BLOCKCHAIN- A CASE STUDY IN PEER-TO-PEER ENERGY TRADING: A REVIEW

Mrs. Sonal I Shirke[1], Dr. Payal Bansal[2*]

Article History: Received: 09.05.2023 **Revised:** 20.06.2023 **Accepted:** 01.08.2023

Abstract

Intelligent gadgets when are stacked on top of one another, smart residential and smart industries are created. They all require help from an intelligent power source in order for them to operate at their full potential. Peer-to-peer (P2P) energy trading has become a highly encouraging option that promotes a comprehensive shift towards sustainable energy sources. It enables flexible and localized trading of surplus energy produced by diverse distributed energy resources which are smaller in scale. It enables individuals to directly engage in energy transactions within their community, promoting efficiency and encouraging the utilization of renewable energy. Nevertheless, the utilization of a software platform is essential, as it facilitates peer-to-peer information sharing and helps system administrators keep an eye on and manage the distribution network. Additionally, the platform's various trading regulations have a big impact on the choices that peers make when trading with other peers. Consequently, the energy trading industry has embraced blockchain technology as a platform to facilitate peer-to-peer (P2P) transactions, enabling efficient and real-time monitoring, trading, and electricity consumption. Incorporating blockchain into the electricity generation infrastructure offers numerous potential benefits and advantages.

Index Terms: blockchain, distributed energy resources, distribution network, Intelligent power source, optimal and real time monitoring, Peer-to-peer energy trading

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[1]Research Scholar, Poornima University, Jaipur,
[2]Poornima University, Jaipur

Email: [1]2021phdoddsonal10422@poornima.edu.in, [2*]payaljindalpayal@poornima.org

[*]Corresponding Author:
Dr. Payal Bansal[2*]
[2*]Poornima University, Jaipur
Email: [2*]payaljindalpayal@poornima.org

DOI: 10.31838/ecb/2023.12.s3.783

1. Introduction

Environmental impact from a heavy reliance on burning fossil fuels for energy production is enormous like in terms of greenhouse gas, air pollution etc). Hence, renewable energy sources will undoubtedly become more prevalent in power generation. All energy sources look to be dominated by wind and solar energy, and this trend is certain to continue into the future. Today, we consider ourselves to be "consumer societies," where people mostly act as passive consumers. However, individuals are encouraged to engage in both productive and consumptive roles by the rapid development of distributed renewable resources, like photovoltaic (PV) systems and energy storage systems (ESS) [1]. In today's landscape, individuals have transformed into proactive prosumers, actively participating as both producers and consumers, rather than simply being passive consumers. [2]. In light of this scenario, the adoption of feed-in-tariff (FiT) has become prevalent, enabling prosumers for their active participation in the energy trading market. Under the FiT system, prosumers who have rooftop solar panels can effectively contribute to the grid by selling any excess solar energy they generate. Conversely, they have the flexibility of buying energy from the grid in case of a shortage in their own generation. Unfortunately, prosumers have only received a very small gain from taking part in recent FiT programmes. Because of this, there aren't many prosumers that engage in energy trading [3]. Peer-to-peer (P2P) trading has evolved as a compelling substitute for prosumers seeking active engagement in the market of energy. P2P trading facilitates the exchange of energy which has been produced in excess among prosumers, creating mutually beneficial outcomes for both the sellers and buyers. This approach not only empowers end users with greater freedom and opportunities to utilize clean energy but also contributes to the transition towards a low-carbon energy system. Moreover, P2P energy trading brings advantages to other participants in the power market as well. By reducing peak electricity demand, it enables cost savings in terms of operation and maintenance expenses. Furthermore, the reliability of the electrical system can be enhanced through the distributed nature of P2P trading. [4]. Consumers actively manage their energy production, usage of energy, and ESS for financial or environmental incentives [1]. In the realm of sustainable energy, prosumers have the opportunity to form peer-to-peer microgrids or communities with established guidelines that encourage the sharing of local renewable resources. Leveraging devices which are driven by advanced communication and information technology, this approach has demonstrated effectiveness, safety, and tremendous potential for the future of sustainable energy. [1]. A smart grid provides a way to combine all of the above. Operating and managing the traditional grid with the aim of maximizing electricity distribution and usage efficiency can be challenging due to the system's limited consideration of individual users' electrical demands and preferences. However, a feasible technological alternative to the conventional grid is the implementation of a smart grid with an advanced communication network. A smart grid employs a state-of-the-art infrastructure that incorporates advanced technologies to distribute flexible loads based on the detected electricity needs of users. Unlike the traditional grid, the smart grid integrates computer systems, sensors, actuators, controllers, and network communication protocols. This comprehensive setup enables effective management of energy generation, transmission, and distribution throughout the grid. [5].

However, despite the advantages and opportunities that P2P trading can offer the energy system, there are still many design and operational issues that must be resolved before it can be fully utilized. These challenges can be categorized into two main aspects: the ones related to the P2P market structure and the ones allied with security, data storage, and monetary transactions. The market design for the P2P structure needs to fulfill specific performance parameters, such as cost efficiency or social welfare, to ensure its effectiveness. In addition to achieving these broad goals, a well-designed market should include a number of additional features. To maintain integrity within the market, it is crucial to prevent deceptive practices such as falsely reporting actual cost functions. Transparency and accuracy in cost reporting are essential for reliable market operations. Furthermore, the market architecture should be designed to be adaptable and flexible, allowing for the trading of diverse market goods. This includes considering the various types of local energy devices that may be involved in the trading process. By accommodating different energy sources and technologies, the market can effectively facilitate transactions and support the integration of a wide range of sustainable energy solutions. Without disclosing the prosumers' real identity, it should also safeguard their privacy. Additionally, costs of transaction should be lower, which it can do if it is completely decentralised and lacks a single market operator. Finally, decentralised market designs should use effective market clearing procedures that maximise revenues while safeguarding the privacy of prosumers. To establish a comprehensive and robust peer-to-peer (P2P) energy market, it is crucial to address additional challenges linked to data storage and security. Creating a secure and reliable distributed system that ensures the immutability, visibility, and invulnerability of all transactions is imperative for P2P market mechanisms. Efforts must be made to overcome obstacles in data storage and implement robust security measures. This entails developing a system that safeguards the integrity of transaction records, making them tamper-proof and resistant to unauthorized access. By integrating such measures into P2P market mechanisms, a safe and reliable environment can be established, instilling confidence among participants and facilitating the smooth functioning of the energy market. Price signals and energy costs may be efficiently sent to all prosumers by providing an automated trading and billing system, encouraging greater active engagement in energy trading. Blockchain technology indeed holds great potential for enhancing the secure exchange of data and energy. [6].

In light of the aforementioned, the following contributions are made by this study in an effort to present an outline of major developments in existing P2P energy trading research that are transforming the forthcoming energy sector:

- We cover the history of peer-to-peer energy trading, its difficulties, and a gist of the research conducted by many researchers in this sector.
- We cover the basics of blockchain, examine the usage of blockchain in the trading of energy, its important features, the many factors to be taken into account when utilizing blockchain for energy trading, as well as the research that has been done in this area.
- We offer a quite a few study avenues that would be worthwhile to explore as expansions of the way that research is currently done.

2. Background

2.1) Peer-to-peer Energy Trading

2.1.1) P2P energy trading in a Microgrid

In the realm of computer science, resource sharing is a fundamental aspect where computers play a crucial role in storing and delivering resources. Among the various models used for resource sharing, the peer-to-peer (P2P) network has gained significant popularity, particularly for its effectiveness in facilitating resource sharing among peers located at the network's edge. A community microgrid can be modelled as a P2P network since it consists of several prosumers who live nearby and each have their own generation and demand. In the prosumer-based community microgrid, a P2P energy trading paradigm appears to be appropriate for energy trading [7]. Microgrids are always decentralized. They have various advantages over centralized grid like-

- In microgrids, the power generation plants are located within the locality unlike that of centralized grids which are located in the outskirts.
- Unlike that of centralized grid, since microgrids use many distributed energy resources, it has minimum chances of blackout even during natural disastors.
- Renewable energy can be used extensively in the microgrids.
- Power and data flow in a microgrid is birectional (consumer-grid and grid to consumer) which makes the grid smarter.
- Such smart microgrids enable P2P energy trading and make the system more efficient and reliable.

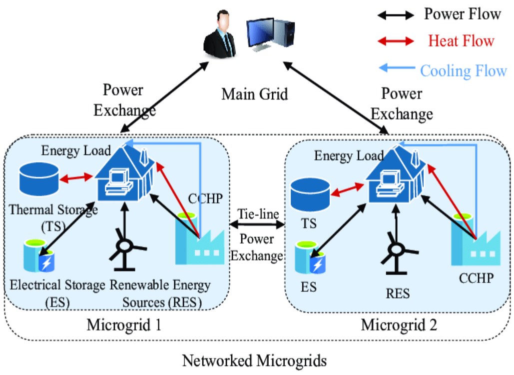

Fig. 1: Networked Microgrid

P2P trading is based on the distribution system's microgrids' structure. As a result, it necessitates both the exchange of information between prosumers as well as electrical lines. Fig. 1[8] depicts the architecture of microgrid networks. Two microgrids are linked to the main grid in this diagram. Resources for distributing electricity make up the microgrid. Typically, consumers generate their own electricity using renewable energy. The peer-to-peer (P2P) paradigm actively promotes demand response (DR) within a community by leveraging the available resources. [7]. Prosumers and consumers are connected for the purpose of trading energy in this microgrid. The microgrid can function as a standalone grid or connect with the main grid for power exchange.

2.1.2) P2P Structure for Exchanging Energy

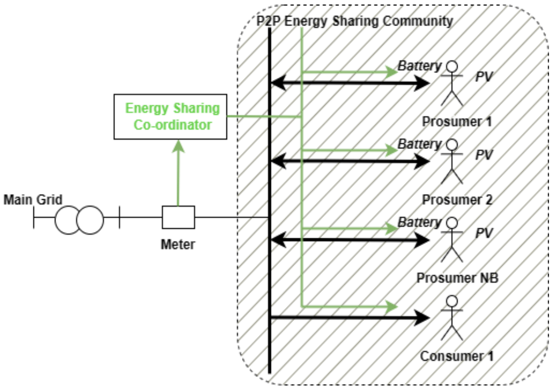

Fig. **2**

The below illustrates the architecture of the peer-to-peer (P2P) energy sharing system. [9]. N clients participate in the sharing network of P2P trading, NB of whom have installed individual PV systems. Despite the fact that a community's PV outputs are probably similar because of nearly identical solar radiation, prosumers' net loads differ. The prosumers can therefore exchange energy with one another. Prosumers' excess energy can also be exchanged with users without PV installations.

A third party organisation namely the "Energy Sharing Coordinator (ESC)" organises client interactions and offers peer-to-peer (P2P) sharing services, such as ensuring the payment and power balances. The DERs are controlled by the ESC, which also runs the neighbourhood market. The PCC is where the ESC is located (e.g. the low voltage substation). At the PCC, a smart meter has been installed to track the community's net energy consumption in real time. This data serves as the ESC's input. One-way communication is used between the ESC and the prosumer premises' controllers of these small-scale batteries to transmit control signals. By effectively controlling the flow of energy into and out of batteries, the Energy Storage Controller (ESC) optimizes the utilization of local energy resources, to minimize the volume of energy sent back to the grid. As a result, the community's total energy costs are decreased, and the lower costs are then dispersed to specific users via a pricing mechanism of P2P. The ESC also determines each customer's individual energy bills using the pricing mechanism of P2P and the energy import/export data recorded from the location's smart meters (eg. Half hourly) .

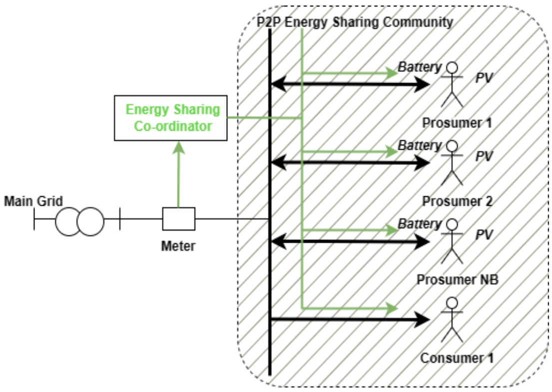

Fig. 2. Energy Sharing Architecture

The ESC, consumers, and prosumers are the three different player types that make up the P2P sharing community.

2.1.2.1) Energy Sharing Co-ordinator(ESC):

The ESC performs several key functions:

- It facilitates the integration of power from the main grid, allowing for the efficient distribution of electricity within the community to maintain a stable power supply.
- Establishes contractual agreements with electricity suppliers, setting predetermined prices for the trade of exported or imported electricity, while also ensuring the community maintains a balanced payment record with the provider.
- Regulates the flow of energy into and out of batteries within the system.
- Facilitates individual prosumer contracts, allowing individuals to engage in specific agreements within the energy ecosystem.

2.1.2.2) Prosumers:

- Enter into a contract with the ESC, Authorize the transfer of battery control to the ESC.
- Individuals have the option to pay or be reimbursed for their electricity bills based on the Peer-to-Peer (P2P) pricing mechanism. This mechanism determines prices 24 hours after the actual electricity usage, following a predefined pricing process.

2.1.2.3) Consumers:

Engage in a contractual arrangement with the ESC and settle their electricity expenses based on the peer-to-peer (P2P) pricing mechanism, which calculates prices 24 hours after actual usage, in accordance with the predefined pricing structure.

2.1.3) Important aspects/challenges for P2P energy trading

Various researchers have worked on the various aspects of trading of energy among peers in a decentralized manner.

TABLE 1 summarizes the various challenges faced during the P2P trading and the work done to cater to those challenges.

It helps us understand that the basic challenge in executing the energy trading among peers is the choice of the platform on which trading has to be done. The platform chosen should provide immutability, transparency, privacy and security in the trading of energy as well as billing settlement. This leads to the use of the blockchain technology for the deployment of the P2P.

Given this background of P2P energy trading, it helps us understand that the basic challenge in executing the Peer-to-Peer trading is the choice of the platform on which trading has to be done. The platform chosen should provide immutability, privacy, security and transparency in the energy trading as well as billing settlement. This leads to the utilization of the blockchain for the deployment of the Peer-to-Peer trading.

2.2. Blockchain

2.2.1) Blockchain-A Distributed Ledger

The Blockchain technology is a well-known building block of cryptocurrencies (like Bitcoin), but it also has a wide range of other potential applications. Blockchain's fundamental component is a P2P distributed record which is irreversible (very difficult to alter), secure and can only be updated by consent among peers [10]. By design, it is transparent and somewhat secure against manipulations [11]. It was first used when bitcoin was created in 2008, and then it was put into use in real life in 2009 [10]. Like traditional bank records, all

TABLE 1: Challenges faced during P2P trading

Challenge	Overview of the study	References
Network voltages and power flows	Analysis of P2P energy trading in aspects of network voltages and power flows is done. OpenDSS distribution network simulator was used.	[12]
Energy trading in various communities	An intra-community and inter-community energy sharing method was applied. The proposed model is proven as energy efficient and cost competitive and can be implemented in real stage	[1]
Opportunistic use of prosumer batteries	A game framework based on coalition formation for the energy trading between the peers for the opportunistic use of prosumer batteries for the participation in the energy trading process	[13]
Market clearing objectives, Systematic categorization of market participants	Criteria like network constraints management, scalability and the overhead requirements was used for analyzation. Market clearing can be facilitated through the implementation of distributed methods. It ensures reduction in communication and computation overheads due to its distributed nature	[14]
Minimization of the energy costs	A two staged energy trading method was used. The initial stage involves a constrained non-linear programming (CNLP) optimization with a rolling horizon approach. In the subsequent step, a control method which is rule-based is implemented.	[9]
Avoid storing of energy in the prosumer community	The M-leader and N-follower Stackelberg game approach was used.	[7]
Trading platform to be used	Discusses on use of blockchain, approach of game theory, optimization, simulation, and different blockchain algorithms	[4-6],[15-34]

Transactions are stored on blocks, but with the added benefit of eventually creating a distributed global public ledger. Each block in a chain of blocks, excluding the initial one called the genesis block, relies on its hash value to uniquely identify the block that comes before it. [35]. Additionally, the term "blockchain" refers to the grouping of the blocks into chains. By utilizing a secret key and a cryptographic hash function, it becomes feasible to digitally sign a transaction. This process is made possible because each individual or node possesses a unique pair of a secret key and a corresponding public key. Other nodes utilize the public key to authenticate the transaction's legitimacy, ensuring that the individual whose digital signature is attached to it has indeed authorized it. Since every user has a record of every transaction, every user may confirm the history of transactions by looking through the records they own. A P2P network is the foundation of the entire system. The database is kept distributed by nodes, which also decide which transactions those will be allowed. Participants receive rewards for their contributions to the system's viability, a process known as mining [35]]. Unvalidated transactions cannot be stored in the block. Blockchain thus upholds data security, decentralization, and integrity [36].

2.2.2) Elements of a Blockchain

Following are the elements involved in the blockchain technology [37]:

- *Block:* A block comprises two main components: a header and a body. The header holds essential information like the timestamp, the hashes of the previous and current blocks, and other relevant data. On the other hand, the body primarily encompasses the particulars of the transactions being recorded.

- *Node:* The fundamental building block of the blockchain network, responsible for preserving the entire blockchain and disseminating transactions across the network.
- *A miner node:* It is a unique node that has the additional capacity to generate revenue by grouping transactions into blocks and connecting those blocks.
- *Peer-to-peer network:* It lacks a centralized control player, every node shares the public ledger.
- *Transaction:* In some jurisdictions, a series of actions, for example - transfer of digital assets, are considered transactions.
- *Consensus:* A decision outlining the method for choosing the miner node that holds the utmost importance in the process of mining and verifying recent transactions.
- *Mining:* Process of creating new blocks and transaction packaging.

2.2.3) Blockchain-The Process

The process of storing the data/transactions in the form of a blockchain involves the following steps:

2.2.3.1) Data Encryption and Signing

A component of cryptography, the data encryption technique helps to ensure the secrecy, integrity, and authentication of data. Although it might not be a comprehensive solution, it can be viewed as a crucial stepping stone in the construction of a safe data environment. Data is encrypted using a cypher such that, even if it is an enemy intercepts it, without a functional decryption process, it is impossible to restore the original data.

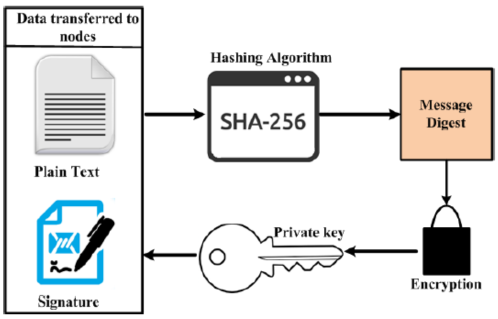

Fig. 3. Data Signing Process in the Network

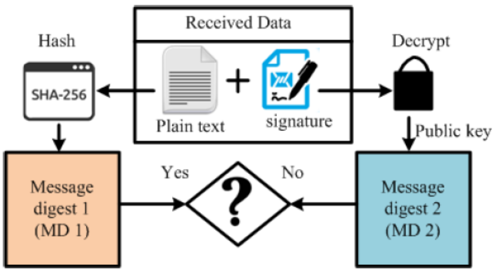

Fig. 4. Data Verification Process

In a network, every node is assigned a pair of keys: a private key and a public key. To ensure the decryption of messages, it is crucial to maintain the confidentiality of the private key, as its name implies. The encryption algorithms utilized can include SHA-256, SHA-384, or SHA-512, with the length of the key, determined accordingly. On the other hand, all nodes within the network have access to the public key and serves as shared information. Data is broadcast to the nodes after it has been encrypted [10]. Fig. 3 [33] explains the process of data encryption and signing process.

Each node's stored data is divided into parts as collected blocks, pre-determined consensus, and information on all nodes' public and private keys. Signatures and plaintext are included in the transferred data, which is broadcast to every other node. By using a secure hash method to process the collected plaintext, a message digest (MD) is produced (SHA). A group of algorithms known as SHA were created to protect sensitive data from various cyberattacks and to prevent them. As a digital signature, MD is encrypted with the use of a key which is private. However, the same node's public key is used for decryption. The transferred data is sent to every other node over the communication channel.

2.2.3.2) Data Verification

The Fig. 4[33] explains the data verification process. Using the sender's public key, the node employs a cryptographic process to transform the plaintext into a secure message digest, referred to as MD1. Additionally, the signature is also hashed into another message digest, denoted as MD2. This is done in order to verify the encrypted data it has received. The comparison of MD1 and MD2 takes place to determine the veracity of the information received, and if the results are equivalent, the information is declared correct; otherwise, it is declared incorrect. This process is seen in Fig. 4. Each verification node should adhere to consensus, or each node should concur on a single conclusion. The attainment of a unanimous agreement among all nodes for establishing a single conclusive outcome is just over 50% in order to reach consensus.

2.2.3.3) Data Mining and Generation of Blocks The

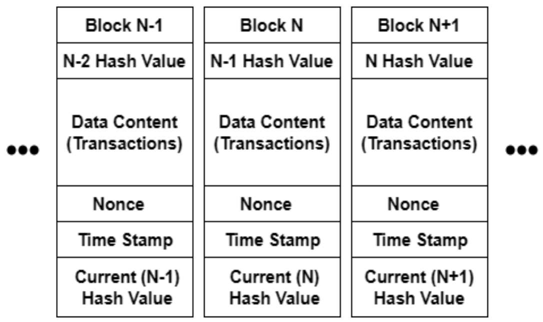

Fig. 5 [10] helps understand the process of mining of data and in turn the generation of block and blockchain.

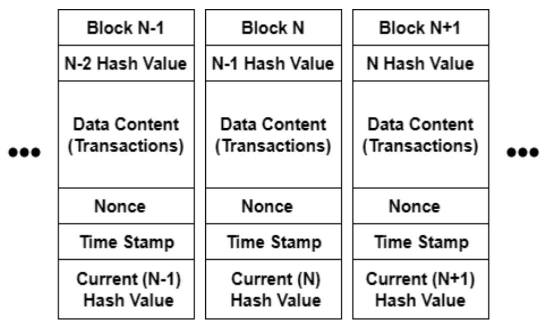

Fig. 5. Block Content and Chain Creation

As seen in the illustration, the data stored within the blockchain network is securely linked together using cryptographic techniques, ensuring a strong connection between each consecutive block. To achieve this, various safe hash algorithms are used such as SHA-1, SHA-256, SHA-384, and SHA-512. The majority of the time, they are created utilizing dedicated and iterated hash function creation methods. There are several families of hash functions that are commonly employed and widely utilized for the purpose of message authentication codes and digital signatures. SHA-256 is used to carry out the mining and block generation process. Each block within the network of blockchain contains the following components: the block's number, the data that is included within it, the time stamp, the previous and current hash values, and the nonce. In order to derive a suitable nonce value for generating a hash specific to the current block, all the nodes engage in the process of mining. The current hash is influenced by both the data contained within the current block and the hash value obtained previously. Therefore, if the Nth block is the current block, the current hash value will be determined by the data in the Nth block and the value of hash of the (N-1)th block. This conundrum is created in the following stage, which is the hash computation process. By applying SHA-256 twice to the entire message (S) in this stage, MD is made even safer. The computational cost of the task rises as the goal hash value decreases because it becomes harder to discover a preferred nonce [33]. The nodes taking part in the puzzle problem solution are known as miners. The nonce value is discovered by a miner and then disseminated to other miners or nodes to verify the integrity of the hash of the target. Additionally, the resulting hash value of a block undergoes modifications within the block itself before it can be securely linked to the previous ledger using cryptographic techniques, resulting in creation of a blockchain, This happens after verification only when a consensus is reached by a majority of over 50% of the nodes altogether [10].

2.2.4) Trilemma in Blockchain

To evaluate the performance of blockchain technology three factors should be majorly considered. Scalability, Security and decentralization are the three major elements contributing to the performance of any system which deploys blockchain technology. In [30] the author's study believes that the current technology of blockchain can achieve only two of the three aforesaid parameters. To maintain a balance between these elements for the application in which the blockchain system is being deployed is a necessity. Hence it is considered to be a trilemma in blockchain.

2.2.4.1) Decentralization: The concept refers to the capacity of a system to function across multiple network nodes, granting each user the privilege to connect to the network. In decentralized systems, consensus is achieved through democratic decision-making processes, where important actions like transaction verification are collectively determined.

2.2.4.2) Security: A system is said to be secure if it can fend off intruders. The lack of a central point that can cause complete system failure is a notable characteristic on a decentralised network, guaranteeing a high level of security.

2.2.4.3) Scalability: Node-scalability and performance-scalability are both parts of scalability. Node-scalability in networks of Blockchain pertains to the capacity of expanding number of nodes in the network without experiencing degradation in performance. It ensures that as the network grows, the system can handle the increased node count efficiently and effectively. Performance scalability in blockchain networks pertains to the system's capability to effectively manage an increasing quantity of transactions without compromising its performance. The primary scalability-related problems are throughput and transaction validation latency. Transaction validation latency, also known as validation and confirmation time, represents the duration it requires for the approval of a transaction and to get added into a block within a blockchain network. Whereas, Transaction throughput (i.e. processing speed), refers to the capacity of validating and processing transactions within the network in terms of their quantity in a given time frame, typically measured in transactions per second (TPS). It reflects the network's capacity to handle and process a high volume of transactions efficiently. The other factors causing the scalability issue are blocksize, number of nodes, storage capacity, computation energy for mining and total cost for transaction validation.

The high level of security and the benefit of decentralization are compromised by the scalability problem that blockchain technology faces. Although there are solutions to the scale problem, security and/or decentralization may still be compromised. By investigating the trilemma implications of blockchain-based energy trade, we can identify challenges, develop solutions, and make informed decisions to promote the successful integration of blockchain in the sector of energy. Hence its study is vital. [30].

2.2.5) Smart Contracts in Blockchain

Smart contracts, first described in 1994 by Nick Szabo referred to "a computerised transaction protocol",that puts a contract's terms into action. The scripts are run to express the way in which transactions are carried out. Smart contracts (SC) are commonly crafted using advanced programming languages like Solidity. Once written, the compilation of smart contract is done into bytecode, which is a low-level representation of the contract's instructions. The bytecode is then stored on the blockchain. Before a SC is linked to the blockchain, it passes through a review process by the involved parties to ensure its accuracy and fulfillment of requirements. Once all parties are satisfied, the contract is deployed to a specific block within the blockchain. The deployment involves adding the contract's bytecode to the block and broadcasting it to the network. The deployed contract undergoes validation by the network's consensus mechanism, which ensures that the contract adheres to the predefined rules and is consistent with the blockchain's state. Once validated, the contract is received and stored by each node participating in the network. From this point onward, the contract becomes an immutable part of the blockchain and can be interacted with according to its predefined rules and functions. This allows it to track the progress of smart contracts in real time [10].

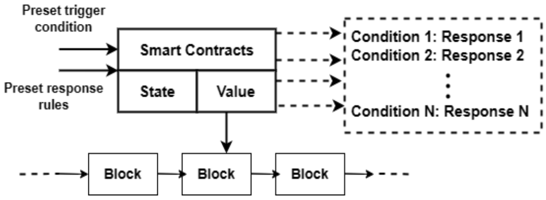

Fig. 6. Working of a Smart Contract

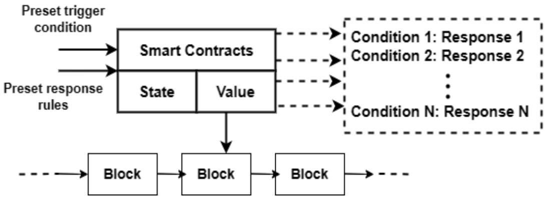

Fig. 6

Depicts the configuration of smart contracts. When it comes to SC, the findings must be predictable; else, they cannot be used. Consensus will never be reached amongst nodes. With the help of this feature, the behavior of smart contracts ensures that, given a specific input, they consistently generate the same output. The P2P energy trading microgrid system can adopt various new technologies with the use of smart contracts. Underlying architectures are necessary to support emerging paradigms like auction mechanisms, demand response and scheduled power consumption, that enable synchronized information and value flow. This architecture should support actions to be taken automatically on behalf of the users of energy, allowing for efficient and effective management of energy resources. Smart contracts enable customizable user behaviours, clear and reliable transaction records, and other features that have a wealth of capabilities to satisfy these needs [38].

2.3) Blockchain in Energy Trading

2.3.1) The Process

A viable method for managing distributed trust in the Distributed Energy Trading (DET) sector without relying on centralised authorities has recently surfaced. Thanks to blockchain technology. Blockchain, as a decentralized shared ledger, provides several advantages such as distributed trust, provenance, and immutability through a network of peers. In the context of energy, a blockchain ledger serves as a repository for recording transactions related to the distribution of assets, which are stored in various accounts. Scholars in the academic sphere and professionals in the energy industry are actively exploring innovative approaches in the form of Distributed Energy Trading (DET) systems that leverage blockchain technology. These solutions aim to integrate traceability, visibility and trust and administration of Distributed Energy Resources (DERs). By utilizing blockchain, these DET systems enable improved visibility into energy transactions, enhance the ability to track and trace the origin and movement of energy, and establish trust among participants in the energy ecosystem[31]. Following are the steps involved in transaction processing in Peer-to-Peer energy trading using blockchain. These are shown in the Fig. 7 [30]. The steps include:

- P2P trading for sharing of energy between prosumers and consumers starts.
- Once energy sharing starts, transactions of payment are started through SC. Smart contracts will analyze tariffs and energy import/export to determine the payment price.
- The payment amount, IDs of the payer and the payee and identification of the block producers are all included in the transaction record. The block is made up of an encrypted list of several transaction records.

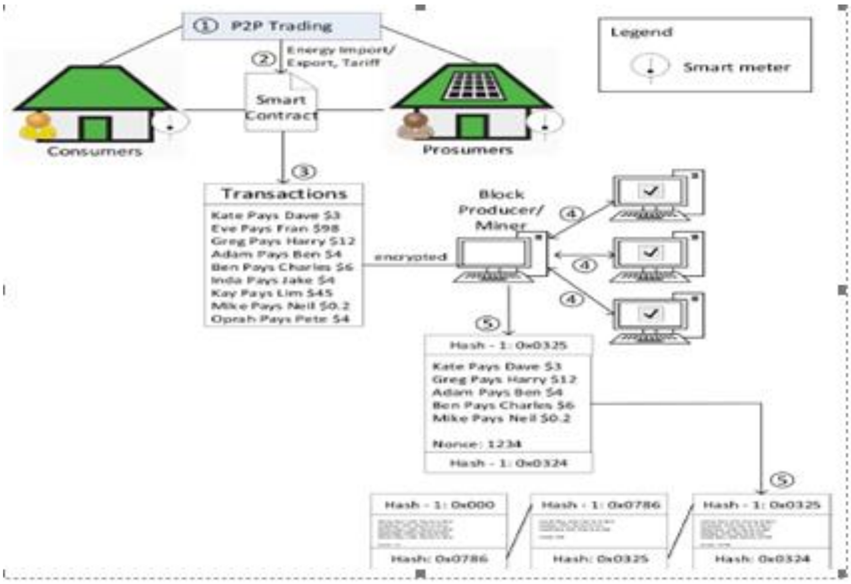

Fig. 7. P2P Energy Transaction Process using Blockchain

TABLE 2: Factors contributing to the use of Blockchain in P2P trading [5-6, 18, 20-22, 25, 29-34, 39-46]

Major factors contributing to use of Blockchain in P2P trading	**Work addressing the given factors**
Decentralization and scalability	1. A blockchain model called SynergyChain was used [29]. 2. A second layer solution was used which utilizes the processing of a number of off-chain transactions and the recording is done on side-chain [30]. 3. A three layered network architechture framework called Hypergraph-based Adaptive Consortium Blockchain (HARB). The bottommost layer addressed scalability issue [31].
Information privacy /security and Economic efficiency	1. Decentralized variation of the Ant-Colony Optimization method, -‘DACO’ was used [6]. 2. Three types of decentralized systems are used-large-scale energy-storage-based trading, Adhoc P2P energy trading and Infrastructure based energy trading model [32]. 3. Byzantine General Problem(BGP) was used for security in energy trading between Distribution Network and the Electric Vehicles against cyber-attacks [33]. 4. A consensus algorithm was proposed [34][29]. 5. A Flexible permissioned ascription(FPA) scheme was proposed which uses permissioning scheme of on/off chain via Metamask wallet and Orion [39]. 6. Alternating Direction Method of Multipliers (ADMM) was proposed [40]. 7. Privacy Preserving Blockchain Energy Trading Scheme(PP-BCETS) was suggested [22]. 8. The encoding method used was in combination with Functional Encryption (FE) [41]. 9. The matching of the peers for energy trading is done on the bids which are encrypted [21].
Avoiding need of any trusted third party	1.Secure Private Blockchain (SPB) was used [42]. 2.Proof-of –concept was used [43].
Reducing the gap of price between buying and selling of energy	1. Proof-of-stake(POS) pricing mechanism based on blockchain was used [44]. 2. Blockchain levelized cost of energy (BLCOE) was suggested for the same [20].
Use of open source software	A NodeRed platform is used for the same [45].

Transaction speed	A cyber-enhanced transactive microgrid model in blockchain was used for the improvement in transaction speed [25].
Quality of service(QoS)	In the deployment of blockchain for smart trading of energy, Ethereum's TestNet version was utilized, leveraging the capabilities of smart meters installed in households connected to smart grids[5],[46],[18].

- The block of transactions is then verified by a blockchain miner, who creates a candidate book that is published to all network participants. The transactions are verified by all network nodes using a consensus method. Typically, miners look for the appropriate accounts to see if participants have any money on hand. If they do, the network will verify and validate the transactions.
- A blockchain is formed through the connection of blocks using hashes and shared block signatures, resulting in a comprehensive record of all previous entries organized in a linked list structure.

TABLE 2 summarizes the different factors to be considered while implementing the blockchain technology in the P2P trading.
It shows that lot of work has been done focused on the decentralization, scalability and security aspects of the blockchain. Some work emphasizes on the Quality of service and gap between the purchase and sale prices of energy in the market.

2.4) Energy trading using blockchain in various sectors:

TABLE 3 depicts the work that is done in the various sectors of energy trading using blockchain.
As can be seen from TABLE 3, work of energy trading using blockchain is done majorly in the sectors of- residences, industries and EVs. Owing to increasing demands of EVs it becomes a necessity explore more in the sector of energy trading between Vehicle-to-vehicle(V2V), Vehicle-to- Grid(V2G) Grid-to-Vehicle(G2V). The success of industrial revolution depends mainly on the management of energy in that sector.

3. Discussion on Future Research Direction

Energy demand is influenced by what individuals do at home, at work, and when they move around and has a considerable impact on carbon emissions and system costs. Analyzing individual energy-related behaviours, daily routines, practise sequencing throughout the day, and variations in energy demand over time and geography are all necessary to comprehend the structure of energy demand. Behavioral theories can explain how people respond to both internal and external stimuli. Examples include how people adjust their load profiles in response to immediate feedback (provided by smart meters in residential sector). Social practices also offer a dependable foundation for comprehending the composition of energy demand. The building (residential and commercial) sector, the industrial sector, and the transportation sector are the three main sectors with the highest energy demand. There is a need to consider the Demand-response of energy to fulfill the consumers' needs. There are various approaches to predicting energy demand, including time series models, regression models, and the artificial neural network approach. Researchers can further explore this area of work for Energy trading using blockchain. A verifiable fairness mechanism to deliver next day energy on already agreed price can be developed using complex smart contracts for transaction settlement. Nevertheless, a simulation model of real world metering and automated trading routines can be developed.

TABLE 3: Work done in various sectors of Energy trading using Blockchain [13, 15-17, 47-60]

Sector	**Work done**
Residential Energy management	1. Scheduling algorithm and demurrage mechanism used- for optimization of energy in residential energy market [15] 2. Permissioned blockchain method- for energy trading in residences. Hyperledger fabric was used to store the energy bids [15] 3. A miner node in the blockchain- selected on the basis of power capacity [13] 4. Two methods used for energy trading. First- based on energy demands and surplus supplies of the members. The other- by considering the physical distances between the participants. [16] 5. The study showcases an interface that connects residential smart metering systems with a blockchain simulator.[17]
Energy trading in Electric Vehicles (EVs)	1. Focused on avoiding privacy leakage and is robust for V2V and V2G networks using blockchain technology. It uses the Proof of authority (POA) mechanism [47] 2. A mechanism of trading based on consortium blockchain, computational intelligence and mechanism based on incentive rooted in contract theory principles was used to focus on

	avoiding privacy leakage [48] 3. To avoid privacy leakage, a protocol in EV charging for making tariff decisions dynamically was proposed [49]. 4. Consumers and prosumers directly meet in a market to satisfy their needs of energy. A Greedy algorithm was proposed for the same [50]. 5. P2P electricity trading system with consortium blockchain (PETCON) was used for energy trading in hybrid EVs [51]. 6. A energy trading framework for Cyber Physical Systems(CPSs) which combines edge computing, contract theory and blockchain [52]. 7. SDN architecture assists the blockchain very well in improving the QoS of the network for energy trading between EVs [53]. 8. Focused on energy transfer in Vehicular Energy Network(VEN) [54]. 9. Focused on reducing the power required for computation and increase the throughput of energy transactions in V2G energy trading network [55].
Energy trading in IIoT	1. Focused on improvement in efficiency of processing and security. System called Block Chain-Energy trading system(BC-ETS) supported by Industrial IoT was suggested [56][88]. 2. Stackelberg game was proposed for optimal pricing strategy [57]. 3. Focused on helping the organization of the P2P market for Large-scale industrial energy consumers [58]. 4. Focused on making involved nodes self-sufficient by the locally stored energy. A new heuristic algorithm was designed for the same [59]. 5. Focused on improving the quality of energy for Industry 4.0 and a trading system for energy which is secure. A scheme called FeneChain was used here [60].

4. Conclusion

The review article consolidates the automated Energy trading mechanisms. Energy trading mechanisms are peer to peer i.e. they engage in energy trading directly among participants without the need for a central intermediary. In residential applications, households should be installed with smart meters which give a further pathway for smart grids and microgrids. Efficient use of electricity, reduction of electricity bill, independence of the main power grid are the key features while energy is traded in the market with the use of distributed energy resources. For reliability and security of trading in energy, the technology backed by blockchain has been used. Smart contracts help in a fair mechanism for transaction settlement. Prediction of energy can be done to have a sustainable microgrid. It aids in maintaining real time equilibrium between demand and supply while reducing the burden on the primary power grid.

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