Energy Trading Using Blockchain

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Abstract - The use of solar and wind energy is increasing and this has resulted in energy excess on homes and industries. However, the traditional grids built around a centralized system rarely make use of this surplus energy. Blockchain technology solves this problem by allowing secure and trust less cross-border micropayments thereby allowing consumers and prosumers to trade directly However, the process of redistributing this energy surplus or excess has been redefined and envisaged in a more decentralized manner which fundamentally uses the blockchain and along with this many inefficiencies hitherto present in the system allow cross border energy exchanges So the combined processes make energy futures tradable at their underlying protocols . This paper presents a blockchain-based energy trading platform designed to promote sustainability, transparency, and cost efficiency. By leveraging blockchain's tamperproof ledger and smart contracts, the platform ensures secure, automated, and trust less transactions without intermediaries like utility companies. Prosumers can sell surplus energy to consumers within their community or grid, fostering efficient utilization of renewable resources while reducing dependency on centralized systems. The proposed platform addresses inefficiencies in traditional grids, incentivizes renewable energy adoption, and reduces transaction costs. By integrating blockchain with energy distribution, this system transforms energy markets, encouraging energy democratization and contributing to global sustainability goals. Challenges and opportunities in implementing such a system are also explored, highlighting blockchain's potential to revolutionize energy trading.

***Key Words*:** Blockchain, HTML, CSS, JS, Java

1.INTRODUCTION

This paper focuses on developing a energy trading system using blockchain technology by integrating blockchain, the platform enables real-time monitoring, automated smart contracts, and dynamic pricing for energy exchanges. Smart contracts automate trading processes, while IoT-based smart meters monitor energy production and consumption in real-time. This system primary goal is energy efficiency, reduce dependency on centralized grid systems, and empower communities to achieve energy self-sufficiency. Blockchain is a distributed digital ledger technology that securely records transactions across multiple computers in a network and contains a list of transactions ensuring immutability, transparency, and security. Blockchain contains of Public blockchain, Private blockchain, Consortium blockchain, smart contracts for trust, scalability.

With the increasing adoption of renewable energy sources and the emergence of prosumers (producers and consumers of energy), there is a need for a more efficient and decentralized platform. Blockchain technology offers an innovative solution by decentralizing energy transactions, enabling prosumers to trade excess energy with consumers directly. The surplus amount of the renewable energy is traded between seller and buyer directly without any third-party interference. The energy trading is done in a user-friendly decentralized platform where individuals or businesses with surplus renewable energy (like solar or wind power) can sell it directly to others in their community or grid. Blockchain ensures secure, transparent, and tamper-proof transactions without relying on intermediaries, such as utility companies. Traditional centralized systems face challenges such as lack of transparency and dependency on intermediaries, making innovation essential.

IOT also plays a primary role, it contains physical devices, sensors, smart meters and data can be exchanged over internet, in this system IoT devices play a crucial role in energy monitoring, data collection, and system automation. Energy Trading System uses Cloud, IOT, Blockchain together. IOT devices collect real time energy data from the users, Cloud Infrastructure stored and processes the collected data for scalability and easy access, Blockchain Network records energy transactions securely and transparently and executing automated smart contracts.

2. LITERATURE SUREVY

AMENI BOUMAIZA, ANTONIO ANFILIPPO (2024) This paper demonstrates the effectiveness of integrating (GIS) and (ABM) to simulate and test a blockchain-based peer-to-peer energy trading platform in Doha, Qatar. This virtual framework supports decision making, enhances energy system resilience, reduces dependency on hydrocarbons, and promotes sustainable energy practices.

LIAQAT ALI, et.al This paper presents a blockchain-based Local Energy Market (LEM) enabling secure and transparent peer-to-peer (P2P) energy trading among consumers, prosumers, and electric vehicles. By utilizing forecasting profiles, trading agents, and a matchmaking engine, the platform optimizes energy dispatch, reduces grid congestion, and lowers operational costs.

JUNAIDIMTIAZ et.al This paper proposes a blockchain-based Decentralized Transaction System (DTS) for secure and efficient peer-to-peer energy trading within microgrids. Leveraging Ethereum blockchain technology, the system incorporates smart contracts, a trust model, and dynamic pricing to ensure data integrity, privacy, and transaction security.

LIANA TODEREAN, et.al This paper proposes a blockchain-based cooperative game model for energy communities, enabling prosumers to balance energy supply and demand efficiently. Using smart contracts and token incentives, the model achieves minimal energy imbalance (0.01%) with fast transaction processing, promoting self-sufficiency and cooperation.

YANJUN ZUO, et.al This study proposes a blockchain-based platform for Renewable Energy Certificate (REC) issuance and trading, aiming to reduce operational costs, enhance transparency, and ensure traceability. By tokenizing RECs and leveraging blockchain features like multi-signature transactions and atomic exchanges, the platform offers a secure and efficient system for REC management.

YU-JIN LIN, et.al This Paper introduces a blockchain-based platform integrating AI and IoT for efficient EV power trading and energy management, reducing costs by 11.55% and optimizing green power use with real-time scheduling and minimal latency ensuring real-time scheduling, reduced costs, improved efficiency, and optimized green energy utilization.

MAZIN DEBE, et.al This paper presents a blockchain-based energy trading solution for electric vehicles (EVs) using an auctioning and reputation scheme. The system ensures cost-effectiveness, security, and reliability by employing a reverse auction for fair competition and a reputation-based approach to select reputable energy providers.

FAISAL JAMIL This paper presents a blockchain-based predictive energy trading platform integrating machine learning and smart contracts to optimize energy trading in smart microgrids. The platform includes real-time energy monitoring, predictive analytics, and a reward model for consumers and prosumers.

SERKAN SEVEN, et.al This paper presents a blockchain-based Peer-to-Peer (P2P) energy trading scheme for Virtual Power Plants (VPP) using smart contracts on the Ethereum platform. The proposed solution integrates auction-based bidding to address cost and security concerns, ensuring efficient and transparent energy trading.

MARTIN ONYEKA OKOYE, et.al. This paper presents a blockchain-based transactive microgrid model with an optimized participant permission protocol to address delays in energy transactions. The proposed solution improves transaction speed by 57.7% compared to traditional methods, with node population proving more influential than block size in enhancing performance.

3. PROPOSED METHODOLOGY

This Methodology focuses on developing an energy trading system using blockchain technology by using blockchain, the platform enables real-time monitoring, automated smart contracts, and dynamic pricing for energy exchanges. Smart contracts automate trading processes, while IoT-based smart meters monitor energy production and consumption in real-time. This system primary goal is energy efficiency, reduce dependency on centralized grid systems, and empower communities to achieve energy self-sufficiency. Blockchain is a distributed digital ledger technology that securely records transactions across multiple computers in a network and contains a list of transactions ensuring immutability, transparency, and security. Blockchain contains of Public blockchain, Private blockchain, Consortium blockchain, smart contracts for trust, scalability.

Physical devices, sensors, and smart meters collect real-time energy data from users, enabling energy monitoring, data collection, and system automation. The collected data is stored and processed in the cloud, ensuring scalability and easy access. The blockchain network records energy transactions securely and transparently, executing automated smart contracts to facilitate trustless energy trading. The ETS utilizes blockchain technology to decentralize energy transactions, enabling prosumers to trade excess energy directly with consumers. The blockchain contains a distributed digital ledger that securely records transactions across multiple computers in a network, ensuring immutability, transparency, and security. Automated smart contracts are executed on the blockchain network, automating energy trading processes and ensuring secure, transparent, and tamper-proof transactions without relying on intermediaries. The ETS enables individuals or businesses with surplus renewable energy to sell it directly to others in their community or grid. The energy trading is done in a user-friendly decentralized platform, ensuring secure, transparent, and efficient energy transactions.

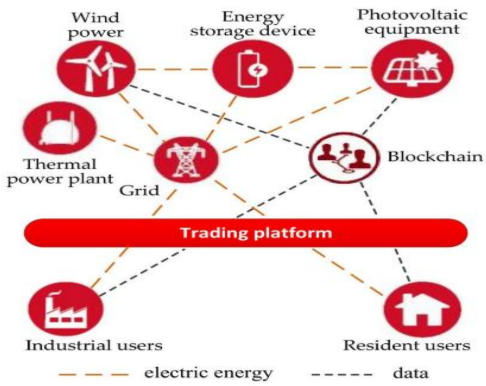

Fig.1 Proposed Methodology of System

The primary goal of the blockchain-based energy trading system is to create a decentralized and sustainable energy ecosystem. This is achieved by enabling energy efficiency and reducing dependency on centralized grid systems. By empowering communities to achieve energy self-sufficiency, the system promotes a more resilient and localized energy infrastructure. Furthermore, the system facilitates secure and transparent energy transactions, while automating energy trading processes through smart contracts.

Algorithm:

- **Step1**: Transaction Creation A new transaction is created and broadcast to the network.
- **Step2**: Transaction Verification Network nodes verify the transaction's validity and consistency.
- **Step3**: Block Creation Verified transactions are collected and formed into a block.

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- **Step4**: Block Propagation The block is broadcast to the network for verification.
- **Step5**: Consensus Algorithm Execution Network nodes execute the consensus algorithm to validate the block.
- **Step6**: Block Validation Nodes validate the block by checking its hash and transactions.
- **Step7**: Blockchain Update Each node updates its local copy of the blockchain.
- **Step8**: Transaction Confirmation Transactions within the validated block are considered confirmed.

4. RESULTS

The blockchain is used as a decentralized overlay infrastructure on top of the local energy grid, offering a secure and reliable network that connects prosumers in the community and enables them to engage in peer-to-peer energy transactions. The energy transactions made among prosumers are registered in a distributed ledger which is setup and shared at the community level, the transactions being traceable and immutable. Operations such as order registration, initiation, and evaluation of coalitions stability, as well as payment and energy exchanges, are registered via the blockchain ledger. The transactions initiated by prosumers belonging to the community are propagated in the community network, grouped in blocks, and mined. After adding blocks to the blockchain network is ensured that the transactions have been previously validated and are now securely registered due to the hashing mechanism and will not be modified or altered. Also, the traceability and transparency of blockchain transactions improves prosumers' trust and enable them to be involved in energy community management. Smart contracts are pieces of code that once deployed on blockchain can't be modified or altered. They enable implementation of self-enforcing algorithms that are executed through blockchain transactions while also keeping data records. By using smart contracts blockchain transactions are associated with some predefined actions that are triggered if the specified preconditions are met. The smart contract code is executed on blockchain in a secure manner. In our solution, the prosumers will deploy smart contracts that store in its state information about their assets and enable the automated registration of prosumer monitored energy data.

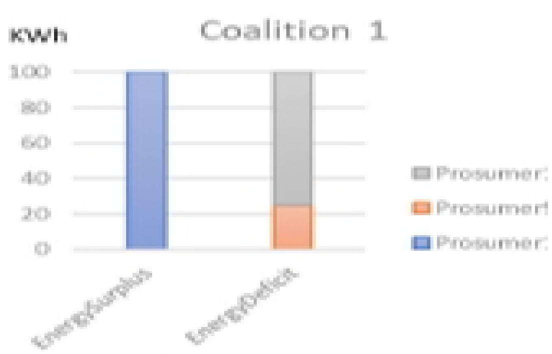

Fig 2: Coalition 1

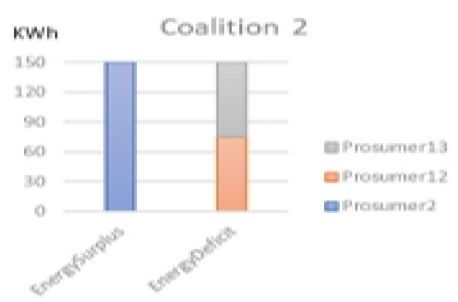

Fig 3: Coalition 2

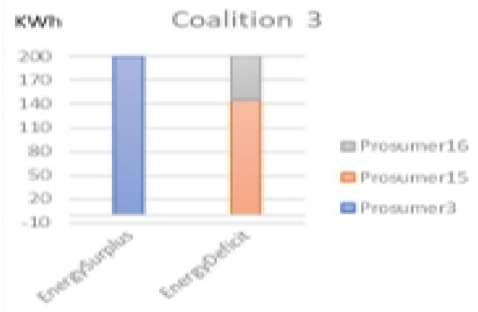

Fig 4: Coalition 3

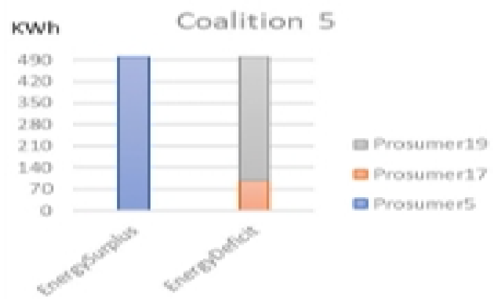

Fig 5: Coalition 4

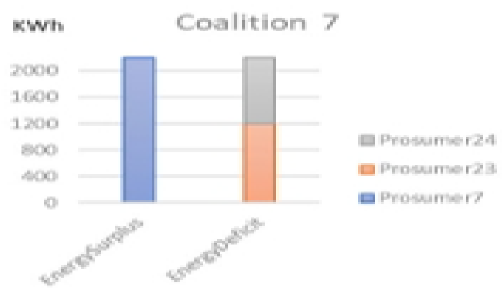

Fig 6: Coalition 5

This Figure 2,3,4,5 and 6 shows the stable coalitions generated in the first stage of the cooperative game. The coalitions created are self-sufficient balancing the energy supply and total aggregated energy demand. The coalition is initiated by sellers by transferring the quantity of LERC20 tokens to the smart contract to be utilized to reward the buyers or self-sufficient prosumers for joining the coalition based on their contribution. The quantity of tokens is determined considering the payoff percentage for self-sufficient prosumers from the energy surplus amount of the seller prosumer. This way, the coalition will have enough tokens to spend even in the case it reaches a stable state only with self-sufficient prosumers that have higher rewards than buyers. ERC721 energy tokens are minted by the prosumers when the coalition is created with the energy surplus quantity and gives the coalition allowance to transfer tokens.

Coal. ID	LERC 20 Tokens	ERC721 Tokens ID: quantity	Pros. ID	Flexibility Used	LERC20 Reward	Received ERC721 Tokens
1	70	0: 100	9	5	14	25
			10	0	30	75
			26	0	0	0
			27	0	0	0
			29	0	0	0
2	97	1:150	12	15	36	75
			13	0	26	75
3	120	2:200	15	0	46	140
			16	20	33	60
5	240	4:500	17	30	44	100
			19	0	112	400
7	1100	6:2200	23	0	216	1200
			24	300	288	1000

Table: Stable coalition and tokens distribution

Table presents the quantity of LERC20 and ERC721 tokens received by the prosumers as rewards for their participation for the stable coalitions. The prosumers check if the initiated coalitions can satisfy their energy deficit and choose the coalition with the highest reward. For example, Prosumer with ID 9 chose the coalition with ID 1 initiated by Prosumer with ID 1. Even though it has an energy deficit of 75 kWh and only 70 kWh are needed to make the coalition stable after the acceptance of Prosumer with ID 10 having an energy deficiency of 30 kWh. Thus, 5 kWh of the prosumer with ID 2 were mitigated by decreasing its consumption by shifting flexibility and will receive an additional reward for the flexibility usage. The coalitions that are partially stable (i.e., ID 6) as well as coalitions initiated by sellers which have not received any request to join from buyers are presented in Figure 5. The coalitions are not self-sufficient, the energy demand and supply being unbalanced thus they are destroyed, and the prosumers members will enter the second stage of the cooperation. At the same time, some prosumers were not accepted in any coalition in the first stage (see Table 4). There are several reasons for this. The prosumer with IDs 11, 14, 18, 20, 22, and 25 requested to join the coalition with ID 1 but was not accepted as the sellers had selected other bids to distribute their surplus. Other prosumers were accepted in partially stable coalitions, being destroyed in the second stage (e.g., prosumers with IDs 21, 4, and 8). The partially stable coalitions that were not selected by any prosumer will be destroyed in the second stage and forming a coalition with their aggregated energy surplus. The prosumers that didn't select a coalition in the first stage because the reward was smaller than their cost associated with flexibility will also enter the second stage (i.e., prosumers with IDs 28 and 30).

CONCLUSION

In This paper, we proposed a cloud-based energy trading system using blockchain technology offers a revolutionary approach to energy trading, promoting a decentralized, secure, and transparent ecosystem. By leveraging the power of blockchain, IoT, and cloud computing, this system enables real-time monitoring, automated smart contracts, and dynamic pricing, ultimately empowering communities to achieve energy self-sufficiency. With its potential to reduce dependency on centralized grid systems and promote sustainable energy practices, this paper has far-reaching implications for the future of energy trading and management.

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