Grenze International Journal of Engineering and Technology, Jan Issue

Empowering Solar-based Energy Trading with Blockchain

Rashmi Ashtagi[1], Diya Shaikh[2], Sejal Jadhav[3], Muaz Shaikh[4] and Shirin Shaikh[5]
[1]Professor, Vishwakarma Institute of Technology/Computer Engineering, Pune, India
Email: rashmi.ashtagi@vit.edu
[2-5]Student, Vishwakarma Institute of Technology/Computer Engineering, Pune, India
Email: {diya.shaikh21, mohamad.shaikh21, sachin.sejal21, shirin.shaikh21 }@vit.edu

***Abstract*— This study examines the potential for blockchain technology to revolutionize the energy trading industry in light of contemporary events. The production of renewable energy is increasing to satisfy rising demand as the limitations of conventional energy sources become more obvious. However, there are still issues with effectively distributing this energy without using middlemen. Blockchain appears as a solution for the creation of smart cities and decentralized energy markets. The peer-to-peer (P2P) energy trading architecture proposed in this research uses blockchain to enable direct energy exchange amongst prosumers. This ground-breaking strategy secures the integrity of energy transactions and addresses the impending shift to diversified energy markets by utilizing the immutability and transparency of blockchain. The discovery opens the door for a more efficient and sustainable energy ecosystem.**

***Index Terms*— Blockchain, smart contract, energy, solar, transactions, cryptography.**

I. INTRODUCTION

The world has shifted significantly in recent years toward renewable energy sources, with solar energy emerging as a leader in this field. In addition to significantly lowering carbon emissions, the widespread use of solar power technology has caused a new era in the way energy is produced, delivered, and used. A critical difficulty is how to effectively capture, exchange, and manage this available solar energy while providing equitable distribution and cost effectiveness. This challenge is even more serious as solar energy generation becomes more decentralized and diffused.

The distinctive qualities of solar energy generation, which are extremely variable and geographically distributed, cannot be accommodated by conventional centralized energy distribution schemes. The examination of novel approaches to enable peer-to-peer (P2P) energy trading among consumers has been inspired by this, allowing excess solar energy to be exchanged directly within regional energy communities. With its fundamental characteristics of transparency, security, and decentralized control, blockchain technology has emerged as a possible facilitator for transforming the trading of solar-based energy.

This paper presents a thorough analysis of the fusion of these two fields and discusses the intersection of solar energy trade and blockchain technology. By providing an efficient, open, and effective framework for energy trading, the main goal is to empower individual prosumers, small-scale energy producers, and consumers. Utilizing blockchain's provided benefits, such as smart contracts and safe journals, presents a fresh way to address the

Grenze ID: 01.GIJET.10.1.133

problems with conventional energy exchanges.
The primary objectives of this research are as follows:
1.Decentralized Energy trade: In this paper, we examine how blockchain's distributed database technology enables direct P2P energy exports, doing away with the need for middlemen and allowing people to take an active role in the energy market.
2.Efficiency Improvement: By automating energy trading through blockchain-based smart contracts, inefficiencies and delays inherent in centralized energy markets can be eliminated, leading to more timely and affordable transactions.
3. Trust and Transparency: Blockchain technology's transparency makes it possible for energy transactions to be monitored and audited, resulting in trust among participants and reduces the possibility of fraud.
4. Grid Stability and Energy Management: By facilitating real-time energy trade, minimizing energy waste, and balancing supply and demand within local energy communities, blockchain can contribute to grid stability.
5. Regulatory and Policy Implications: This paper also explores the possible regulatory and policy opportunities and challenges connected with the introduction of blockchain-enabled solar energy trading systems, including problems with prices, taxes, and market integration.
In order to support sustainable energy solutions, this paper examines how solar energy trade and blockchain technology might work together. We may be able to completely change the dynamics of energy use and production by developing a framework that embodies decentralization and sustainability. Our objective is to provide useful insights for energy stakeholders, politicians, researchers, and technologists through in-depth analysis, real-world instances, and simulations, promoting a more equitable and effective energy landscape

II. LITERATURE REVIEW

The technical landscape has undergone revolutionary changes in the twenty-first century, with blockchain technology emerging as a disruptive force in many industries. The need for improved management, distribution, and trading of energy resources makes the energy sector stand out among these industries as one that is ripe for disruption. The potential for reshaping traditional energy paradigms is highlighted in this literature review, which synthesizes findings from a wide range of research publications that investigate the use of blockchain technology into energy trading systems.
A groundbreaking study titled "Blockchain-Based Smart Contract for P2P Energy Trading in a Microgrid Environment" emphasizes the significance of effective energy exchange within microgrids[1]. This article emphasizes the possibility for direct energy transfers by utilizing the decentralized architecture and smart contracts of the blockchain, increasing transparency and getting rid of middlemen. This issue is also explored in the research on "Blockchain-Based Distributed Renewable Energy Management Framework", where writers explore how[3] blockchain's distributed ledger and smart contracts improve the use of renewable energy while promoting accountability and transparency.
The investigation of a "Blockchain-Based Energy Trading" demonstrates the potential of decentralized[4] platforms by expanding to larger energy markets. This study demonstrates how blockchain can improve efficiency and security in traditional energy trading by automating transactions through smart contracts. The research on "Blockchain-Based Peer-to-Peer Energy Trading System Using Open-Source Angular Framework and Hypertext Transfer Protocol" echoes a similar[5] sentiment by illuminating how blockchain plays a crucial role in enabling user-friendly interfaces and secure communication in a peer-to-peer trading environment.
The exploration of blockchain's possibilities in sustainable energy futures is a common theme in the literature. The "Blockchain-Based Smart Energy Trading Platform Using Smart Contracts" focuses on[2] the ways in which blockchain enables customers to engage as prosumers, promoting a system for the production of sustainable energy. The "Blockchain-Based Lightweight Peer-to-Peer Energy Trading Framework for Secured High Throughput Micro-Transactions" emphasizes the effectiveness and scalability[6] of blockchain-driven micro-transactions, which may influence the future of the energy markets.
The article "A Survey on Energy Trading in the Smart Grid: Taxonomy, Research Challenges and Solutions" offers a thorough taxonomy[7] of energy trading while also highlighting problems and possible answers. "Blockchain Framework for Peer-to-Peer Energy Trading with Credit Rating" presents a novel[9] strategy including credit ratings in blockchain-based trading, while "Peer to Peer Distributed Energy Trading in Smart Grids: A Survey" explores the dynamics[10] of peer-to-peer trading within smart grids.
A decentralized market[11] that is specifically geared for regional energy communities is proposed in "A Decentralized Blockchain-Based Energy Market for Citizen Energy Communities" as an extension of the

innovation. Energy transactions in microgrids now incorporate security[8] and transparency thanks to the "A Blockchain Based Secure Decentralized Transaction System for Energy Trading in Microgrids" project.
These studies highlight the revolutionary potential of blockchain technology in energy trading systems as a whole. This research adds to the ongoing discussion on sustainable energy management by creating decentralized, safe, and effective platforms for peer-to-peer energy exchange. These insights open the door for creative ideas that may change how we generate, use, and exchange energy resources in the future as the energy landscape changes.

III. METHODOLOGY

In this study, we propose a methodology to address the challenge of efficiently trading surplus solar energy within a community or specific region while eliminating the need for traditional intermediaries, leveraging the Ethereum blockchain and smart contracts. The problem statement revolves around the growing adoption of solar energy production, especially by prosumers who both generate and consume solar power. The challenge is to create a transparent, secure, and efficient peer-to-peer (P2P) energy trading system that can unlock the potential of surplus solar energy within a community.
The Ethereum blockchain serves as the foundation of our proposed methodology. Ethereum's decentralized and programmable nature allows for the creation of self-executing smart contracts that automate the energy trading process. This technology is chosen for its scalability, robust consensus mechanisms, and established presence in the blockchain ecosystem.
Our methodology involves designing a system architecture that includes essential components: prosumers, the Ethereum blockchain network, an energy market platform, and a regulatory authority. Prosumers, the individuals or entities engaged in solar energy production and consumption, play a central role. The Ethereum blockchain network acts as a decentralized ledger for securely recording energy transactions through the execution of smart contracts. The energy market platform serves as a digital marketplace for prosumers to list, discover, and trade surplus solar energy, fostering direct P2P trading. Additionally, the regulatory authority oversees and regulates energy trading activities to ensure compliance with local regulations and market rules.
Within the Ethereum network, the heart of our system lies in the use of smart contracts. Smart contracts are self-executing pieces of code that automate the energy trading process, including the validation of transactions, execution of energy trades, and transparent recording of transactions on the blockchain. Data sources include real-time solar energy generation data from prosumers' solar panels and real-time energy market data. These components collectively enable a transparent, secure, and efficient solar energy trading ecosystem powered by Ethereum's capabilities and the programmable nature of smart contracts.
The implementation and testing phase involve developing a prototype based on the defined architecture, with a specific focus on creating and deploying smart contracts for energy trading. This prototype is used to assess the system's scalability, security, and efficiency using either simulated or real data. Testing is crucial to validate the system's performance and reliability in a controlled environment.
Furthermore, the system includes a user-friendly interface that enables prosumers to register, monitor energy generation and consumption, place buy/sell orders, and view transaction history, all of which interact with smart contracts on the Ethereum blockchain. An effective energy pricing mechanism is essential for determining fair and transparent pricing for solar energy based on supply and demand dynamics and real-time market data. Data security and privacy measures are also integrated into the system to protect sensitive information stored on the blockchain.

III. METHODOLOGY

1. *Ethereum Blockchain*: Ethereum is the foundational technology for your project, serving as the decentralized ledger that records and verifies energy transactions. It provides a secure and transparent platform for energy trading and smart contract execution.
2. *Smart Contracts:* Smart contracts are self-executing pieces of code deployed on the Ethereum blockchain. They enable the validation of transactions, execution of energy trades, and the transparent recording of all activities on the blockchain.
3. *HTML, CSS, JavaScript:* HTML forms the structural foundation of your user interface. CSS is responsible for the visual design and layout of your UI. JavaScript is a key programming language for adding interactivity and functionality to your UI.
4. *Solidity*: Solidity is a high-level programming language specifically designed for developing smart contracts on the Ethereum blockchain. As the primary language for Ethereum's smart contract ecosystem, Solidity plays

a fundamental role in enabling the automation of contractual agreements and transactions within the blockchain.

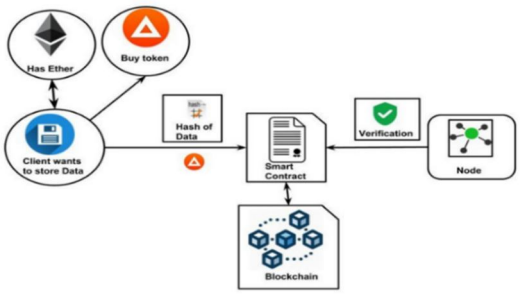

Fig 1. Working of the blockchain

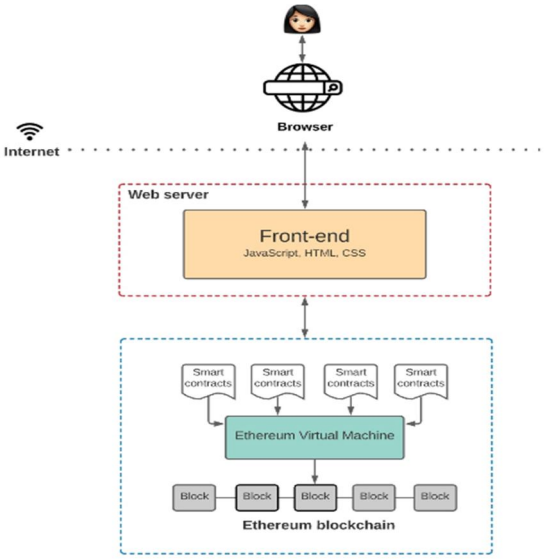

Fig 2. Interfacing UI with backend blockchain

V. Results And Discussion

The implementation of a blockchain-based solar energy trading system has yielded promising results in terms of efficiency and transparency. Through the use of smart contracts on the Ethereum blockchain, energy trading processes have become significantly more streamlined. Transaction settlement times have been reduced compared to traditional methods. This increased efficiency is largely due to the automation of energy trading, with smart contracts automatically executing and validating transactions, eliminating the need for intermediaries.

In terms of transparency and trust, the blockchain has demonstrated its value by providing an immutable and auditable ledger of all energy transactions. Prosumers within the network have expressed a higher level of confidence in the trading system, as the transparency of blockchain technology has significantly reduced the potential for fraud or disputes. The tamper-resistant nature of the blockchain ensures that records of transactions, energy generation, and consumption are accurate and securely stored, instilling trust among participants in the network.

VI. Conclusions

By using a blockchain private network, our proposed energy trading platform reduces security worries. This promotes a transparent peer-to-peer (P2P) system, enhances immutability through automated smart contracts, and does away with middlemen. Circulating virtual energy allows for a huge increase in effectiveness. The combination of blockchain technology and solar energy trade solves problems and opens the way for independent, sustainable energy production and consumption.

ACKNOWLEDGMENT

We want to say how grateful we are for the guidance from Prof. Rashmi Ashtagi and her insightful recommendations during the planning and the creation of this study project. Additionally, we want to thank our college for giving us all the resources need for the project. Overall, we want to thank everyone eengaged in this project and provided assistance to us for improving the project.

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