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P2p Energy Trading Using Blockchain

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Abstract

This project proposes a blockchain-based Peer-to-Peer (P2P) energy trading platform designed to enhance energy efficiency in distributed energy management systems. It addresses the imbalance between users with surplus energy generation and those with energy deficits by enabling direct, decentralized energy transactions. Leveraging blockchain technology ensures secure, transparent, and trustless trading without the need for centralized intermediaries. A mobile application is also developed to provide users with real-time access to transaction details, energy prices, and usage patterns. This system promotes active user participation and aims to create a more balanced, transparent, and sustainable energy ecosystem.

Keywords — Peer-to-Peer (P2P) Energy Trading, Blockchain, Mobile Application, Real-time Energy Data, Renewable Energy, Smart Grid.

1. Introduction

As renewable energy adoption grows, the concept of prosumers—individuals who both produce and consume electricity—is becoming increasingly important. Peer-to-Peer (P2P) energy trading enables prosumers to sell excess energy directly to neighbours, promoting the widespread use of renewable energy. Traditional centralized energy systems struggle to keep up with rising demands, grid congestion, and the shift toward sustainability. Blockchain technology, with its secure, tamper-proof, and decentralized transaction system, combined with smart contracts, offers a promising solution for enabling efficient and transparent P2P energy trading.

Peer-to-Peer (P2P) energy trading is gaining attention as a promising framework that allows prosumers to exchange energy directly with other consumers. This decentralized model increases energy efficiency, reduces transmission losses, and encourages the use of localized renewable energy sources like solar and wind. As renewable energy continues to become more affordable and accessible, more households and businesses are transitioning into prosumers. This shift not only helps balance the load on traditional grids but also contributes to a resilient, sustainable, and user-driven energy future. Combining P2P energy trading with blockchain and smart grid technologies has the potential to redefine how energy is generated, shared, and consumed at the community level.

2. Methodology

The objective of this project is to design and develop a Peer-to-Peer (P2P) energy trading system that enables prosumers to sell their surplus energy directly to nearby consumers at rates lower than conventional energy providers. The system leverages blockchain technology to ensure secure, transparent transactions through smart contracts, eliminating the need for intermediaries. Real-time monitoring of energy usage and generation is achieved using IoT-based hardware, while a dedicated Android application provides users with access to transaction details, energy prices, and system performance. In the future, this system can be scaled to support large communities, integrated with AI for demand forecasting, and connected to national grids for broader energy sharing and sustainability.

3. Literature Review

The authors in Reference [1] proposed an NRGcoin model, also called a novel decentralized digital currency. The model allows locally generated renewable energy from prosumers to be sold using the digital currency organized by the market paradigm of buyers and sellers of green energy in a smart grid.

The authors in Reference [2] presented an adaptive aggressive strategy in a microgrid using blockchain-based Continuous Double Auction (CDA), putting forward a new perspective on an energy market. However, various bid combinations may have distinct initial conditions, and there is an inadequate flexibility to change the bid quantity during the CDA bid process.

Similarly, in Reference [3], the authors presented a secure credit-based system of payment by reducing wait times for transaction confirmation of the energy chain in permissioned blockchain-based Industrial Internet of Things (IIoTs). Reducing the wait time makes electricity trading faster and responses more frequent. The authors also used an optimal pricing mechanism by exploring the idea of stackelberg game theory to optimize bank utility credit-based loans.

The authors in Reference [4] proposed a P2P Electricity Trading system with Consortium blockchain (PETCON) model to conduct secure private P2P trading of energy between plugin hybrid electric vehicles. The study focused on establishing trust and used the anonymous property of blockchains to defend the user's privacy.

In Reference [5-7], an approach based on the power quality perceived by a specific economical category is proposed. However, the proposed model does not consider security issues, privacy leakages, and single point of failure.

4. Implementation

Hardware Architecture

Microcontroller (ESP-12E)- NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language.

PZEM-004T Sensor- The PZEM-004T is a compact and low-cost sensor module used to measure AC electrical parameters such as voltage, current, power, energy consumption, frequency, and power factor. It communicates via a serial (UART) interface, making it ideal for integration with microcontrollers like Arduino, ESP32, and Raspberry Pi. It is widely used in smart energy monitoring systems for real-time tracking of power usage in households or small-scale energy trading setups.

Zero PCB- A Zero PCB, also known as a Perf Board, is a general-purpose printed circuit board used for prototyping electronic circuits. It has a grid of holes with copper pads where components can be soldered to test circuit designs before creating a custom PCB.

Bulb- A bulb is an electrical device that converts electrical energy into light and heat through a filament or LED. It is commonly used as a load in energy monitoring and testing circuits to measure power consumption.

Jumper Wires-Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed.

Female Burg Strips- The female connector is generally a receptacle that receives and holds the male connector**.**

Two Pin Plug- It is used to connect the appliances to the mains.

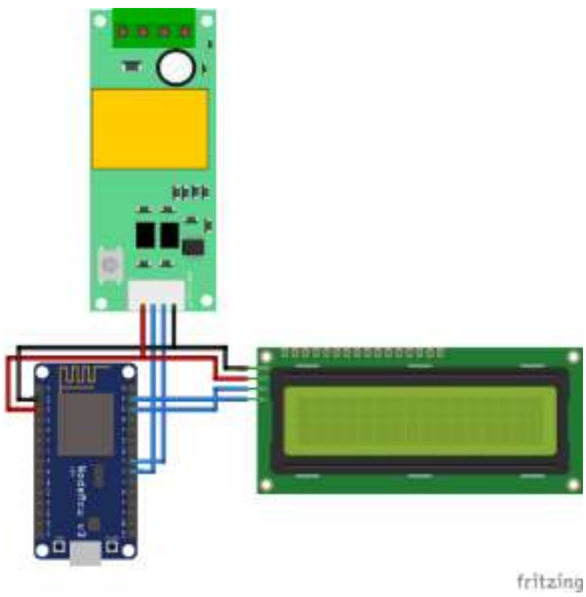

Fig 1: Circuit Diagram of the system

Software Architecture

Spyder- Spyder is an open-source, cross-platform IDE tailored for scientific computing in Python, offering integration with libraries like NumPy, pandas, and Matplotlib.

ThingSpeak- ThingSpeak is an IoT platform that enables data collection, analysis, and visualization, with built-in MATLAB support for advanced processing.

Kodular- Kodular is a no-code, drag-and-drop platform for building Android apps, ideal for beginners and based on MIT App Inventor.

Arduino IDE- Arduino IDE is a cross-platform application used to write and upload C/C++ code to Arduino boards, simplifying hardware programming for embedded systems and IoT projects.

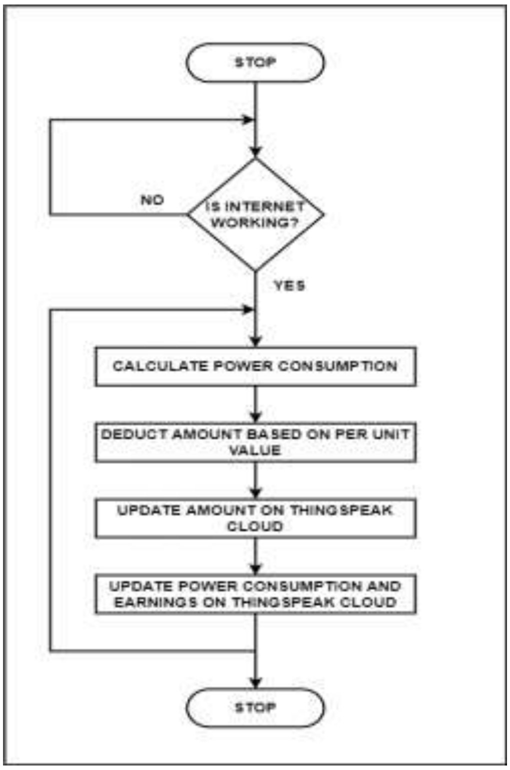

Fig 2: Flowchart

5. Result and Discussion

The proposed Peer-to-Peer (P2P) energy trading system using blockchain was successfully implemented with a focus on decentralization, transparency, and efficiency. The system enabled prosumers to trade surplus energy with nearby consumers at reduced rates compared to commercial electricity providers. Using blockchain technology ensured secure, tamper-proof transactions via smart contracts, eliminating the need for third-party intermediaries.

The integration of the PZEM-004T sensor allowed for real-time monitoring of power consumption and generation. Data was successfully transmitted to ThingSpeak for visualization and logging, and the Arduino IDE was used for microcontroller programming to control and track energy flows. The Kodular-based Android app provided a user-friendly interface to view transaction history, monitor energy pricing, and receive live updates on energy usage and sales.

The system demonstrated:

- Accurate measurement and reporting of energy usage.
- Smooth execution of P2P transactions using smart contracts.
- Effective user interaction via the mobile application.
- Low-latency data transfer and display using IoT integration.

The proposed P2P energy trading system using blockchain demonstrated an efficient and decentralized approach to energy exchange between prosumers and consumers. By integrating blockchain technology, the system ensured secure, transparent, and tamper-proof transactions without the need for a centralized authority. The use of smart contracts automated the trading process, reducing delays and errors. Real-time monitoring through PZEM-004T sensors and data visualization using ThingSpeak provided accurate tracking of energy usage and availability. The Arduino IDE facilitated smooth hardware communication, while the Kodular-based mobile app enhanced user accessibility by displaying transaction details and energy prices. The system proved effective in promoting local energy sharing at lower costs and encouraging user participation. It holds strong potential for future expansion with features like AI forecasting, solar energy integration, and large-scale deployment in smart grids.

Fig 3: Hardware Setup

6. Conclusion

The proposed P2P energy trading system supports both C2C and B2C models, promoting the use of clean, renewable energy with low maintenance needs after setup. It has strong potential for deployment in both urban and rural areas. Future enhancements may include AI-based energy forecasting, personalized trading suggestions, carbon footprint tracking, and dynamic pricing. A dedicated cloud server and private blockchain can further improve performance, data security, and scalability, making the system more efficient and user-friendly.

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