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Peer Chain TradeNet: Bridging Buyers and Sellers through Blockchain

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Abstract---- In residential microgrids, solar power generation in rooftop is becoming more common. A new concept of electricity markets, such as peer-to-peer p2p auctions where consumers and prosumers could exchange locally generated power directly with each other without the aid of an intermediary third party for sustainable development, is also emerging. The security of data is a major issue for energy trading; therefore, the use of blockchain technology in power markets has become more widespread. It could facilitate the trading of power from P2P sources. This framework provides, diverse trading timeframes and metering intervals, simulations that run significantly faster than real-time, flexibility in adjusting the number of participants, managing multiple microgrids under a single smart contract, uses clearing mechanism, the capability to record and track data exchange on blockchain, and the ability to modify price ranges as needed.

Keywords: *P2P, Smart Contract, Smart Meter gateway, Blockchain, Total Energy Coin.*

I. Introduction

The traditional energy market refers to the conventional system of producing, distributing, and consuming energy resources such as fossil fuels (coal, oil, natural gas) and nuclear power. The traditional energy market heavily relies on fossil fuels, which have historically been the primary sources of energy for electricity generation, transportation, and industrial processes. Energy production is usually centralized in large power plants, which burn fossil fuels or utilize nuclear reactions to generate electricity. This electricity is then transmitted through a grid system to homes, businesses, and industries. The energy landscape is evolving rapidly, with a shift towards cleaner and more sustainable energy sources, driven by environmental concerns, technological advancements, and changing consumer preferences. The traditional energy market is undergoing significant transformation to accommodate these changes.

In recent years, there has been a growing emphasis on transitioning from the traditional energy market to cleaner and more sustainable energy sources, such as renewable energy (solar, wind, hydro, geothermal). Renewable energy technologies enable decentralized energy generation, allowing individuals, communities, and businesses to produce their own electricity through rooftop solar panels, wind turbines, etc. With the integration of advanced technologies, the concept of smart grids has emerged. These grids leverage digital communication and automation to optimize energy distribution, monitor consumption, and manage demand more efficiently.

A smart grid is an advanced and modernized electrical grid infrastructure that incorporates various technologies to enhance the efficiency, reliability, sustainability, and security of electricity generation, distribution, and consumption. Smart grids include

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smart meters that enable two-way communication between consumers and utilities. This allows for real-time monitoring of electricity usage, remote reading of meters, and the ability to implement time-of-use pricing. Within the current energy market framework, surplus renewable energy generated by producers is fed directly into the grid, and in exchange, these producers receive a specific economic reward proportional to the excess photovoltaic power they contribute to the grid. The incentive is very small compared to the costs incurred when producing photovoltaic energy. Consumers pay an extremely high price for the delivery of power instead of receiving any incentives to use the grid. Consequently, neither the producer nor the consumers derive any advantage from this energy market arrangement. This issue can be addressed through the implementation of a peer-to-peer (P2P) market.

Peer-to-Peer (P2P) energy trading systems [1] are innovative approaches to electricity distribution that allow individuals and entities to buy and sell energy directly with one another, using blockchain technology. These systems aim to decentralize the energy market, empower consumers, encourage the utilization of renewable energy sources, and improve energy efficiency. In peer-to-peer energy trading the producers generate excess electricity from sources like solar panels or wind turbines. Smart meters measure energy production and consumption, and blockchain technology is often used to record and verify transactions securely. Producers can offer their surplus energy for sale directly to nearby consumers, and consumers can buy energy from these local producers. Smart contracts automatically execute transactions based on predefined conditions, ensuring transparency and trust among participants. Participants in P2P energy trading systems can negotiate prices among themselves, potentially leading to more dynamic and competitive pricing compared to traditional energy markets. By enabling consumers to buy energy directly from nearby producers, energy losses associated with long-distance transmission are reduced, leading to increased energy efficiency. P2P energy trading projects include the Power Ledger platform in Australia, the Brooklyn Microgrid project [2] in the United States, and various initiatives in Europe and Asia. These systems are still in their early stages in many regions but hold significant potential to revolutionize the energy market and contribute to a more sustainable energy future.

II. Related Work

Many literature works explain about a microgrid energy market model that makes use of blockchain technology to streamline the coordination of scattered power generation, distribution, and consumption [3 – 7]. T. AlSkaif et al. [4] devised a decentralized, fully peer-to-peer (P2P) energy trading market with two distinct strategies: the Supply-Demand Matching strategy and the Distance-Based Matching strategy, which help determine the preferences of participating households for bilateral trade. These strategies have the potential to reduce residential costs, decrease overall energy imports from the primary grid, enhance efficiency, and potentially alleviate grid stress. H. Huang et al. [7] proposed a framework for a scalable energy trading network using blockchain, consisting of four planes: the Data plane, Consensus plane, Smart plane, and Application plane. Saini et al. [8] established an energy trading platform within a residential microgrid environment, employing Proof of Work (PoW) enabled smart contracts and blockchain technology. This platform was introduced to reduce reliance on trusted peers for transactions and enhance data authenticity and reliability. The study demonstrated that the trading platform offers both buyers and sellers the opportunity to benefit financially from participating in the trading process. Zafar et al. [9] provided an extensive overview of peer-to-peer energy exchange, addressing aspects such as decentralization, scalability, device reliability, and the potential for blockchain to enhance transparency and overall performance. The article highlights that many blockchain solutions tend to treat blockchain as a 'black box,' limiting the scope for optimizations that could be integrated into smart contracts to influence overall design and performance. Instead, the blockchain can be tailored to specific energy trade requirements rather than being treated as a one-size-fits-all solution. Abdollah et al. [10] proposed a suitable blockchain architecture designed for a secure peer-to-peer energy market. The study included modeling and executing a fault data injection attack to assess and confirm the faulttolerant system's resilience to cyberattacks. This involved the creation of an unscented transform-based stochastic framework.

III. Proposed Work

In Peer-to-Peer (P2P) energy trading, prosumers are required to provide details such as the maximum energy they can generate, the minimum cost per unit they expect for their electricity, and the timeframe for their electricity generation. Consumers, on the other hand, specify their electricity demand, the highest price they are willing to pay per unit, and their consumption schedule. Afterward, the market undergoes a clearing process, and prosumers receive Total Energy Credit (TEC) in exchange for the electricity they have supplied to the microgrid, which consumers have paid for.

A. System Architecture

In Fig.1, the smart meter gateway (SM) is configured with a Raspberry Pi, which operates as a Parity Ethereum client (Blockchain node) alongside Python software, functioning as a BC-SM (integration of blockchain in the smart meter) node. This node is jointly owned by both prosumers and consumers, serving as a means to measure and transmit information about energy consumption or generation to the Blockchain network. Within this context, the term 'public electricity' is regarded as a singular entity referred to as a ‘utility’. To establish communication with the blockchain network, both utility providers and electricity traders possess a user application. This application is utilized by the smart contract operator to create new users, initiate initial token transfers, and update smart contracts. In this particular model, four distinct smart contracts have been developed to facilitate the transfer of Total Energy Credit (TEC), the distribution of awards, TEC deduction, and the conduct of market auctions for energy. The scripts for these contracts are crafted in Solidity using the Remix Integrated Development Environment (IDE), and subsequently, the contracts are deployed onto the blockchain network through Remix.

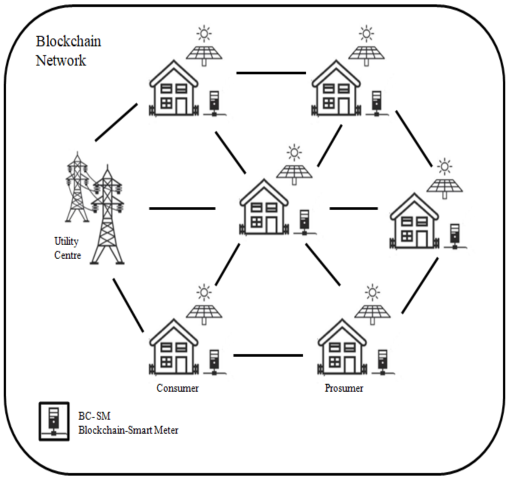


Fig 1. Blockchain Network

B. Smart Contract

In this section, Fig 2. Illustrate the smart contract used for an energy trading.

ERC-20: “Ethereum Request for Comments 20,” [13] It is a standard for creating fungible tokens on the Ethereum blockchain. Fungible tokens are digital assets that are interchangeable with one another, where each unit of the token is identical and can be used interchangeably with any other unit of the same token. After the token is generated, it is allocated to smart contract operator.

Double-side Auction: Within this contract, the bidding process takes place, and orders are matched according to their proximity and associated costs

[16]. This contract leverages the ERC-20 standard to verify user balances and facilitate order matching.

P2P: This contract serves the purpose of establishing a virtual microgrid and user account for energy reception, overseeing the matching process, and subsequently transmitting settlements to the microgrid. The interaction between the blockchain node and the contract involves the transmission of energy consumption or production amounts.

Clearinghouse: The clearinghouse functions as an intermediary positioned between the buyer and seller, verifying that both parties possess the required funds to complete the trade. Smart contracts can streamline this procedure by securing the assets of both parties until the trade is successfully completed [14]. It also serves as a temporary repository for tokens.

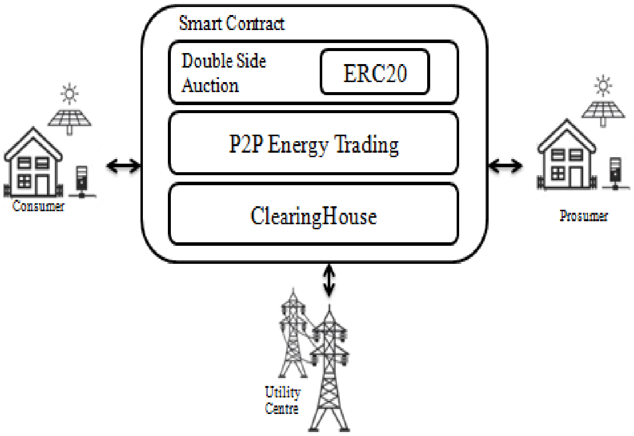


Fig 2. Smart Contract

C. Energy Trading Mechanism

The process of clearing P2P energy trading is explained in Fig 3. Here are, two pricing mechanisms: Equilibrium Price (EqP) which is the market clearing price, and Discriminatory Price (DiP). During the order submission phase, bids are depicted as $B_{i,Nb}$, where Nb signifies the total number of bids. Each bid includes B_{ip} (the maximum price the consumer is willing to offer), B_{iq} (the quantity of energy they require), and B_{it} (the consumption time).Similarly, ask requests are represented as $B_{k,Na}$, with Na denoting the total number of ask orders. Each ask request comprises S_{kp} (the minimum price the producer is willing to accept), S_{kq} (the quantity of energy they are prepared to sell), and S_{kt} (the delivery time)

$$\text{Bids: } B_{i,Nb} = \{ B_{i,p}, B_{i,q}, B_{i,t}\}$$

$$\text{Asks: } B_{k,Na} = \{ S_{k,p}, S_{k,q}, S_{k,t}\}$$

Considering consumption and delivery time factors, these bids and asks are organized into an array spanning the next 24 hours, setting $T_n = 24$ the period of energy trading. Bids and asks are kept in separate arrays for each time slot. Subsequently, this contract examines whether there is consensus among the smart meters participating in the microgrid. This contract is triggered by each smart meter every minute. The clearing process concludes when consensus exceeds 51%. In cases where consensus falls below 51%, a sorting process is initiated.

The sorting entails arranging bids in descending order based on $B_{i,Nb} \geq B_{i+1,Nb}$ (sorted by buying price), and arranging asks in ascending order based on $B_{k,Na} \leq B_{k+1,Na}$ (sorted by selling price). The count of matched buy and sell orders is maintained using two integers, denoted as j and r, both initially set to zero. These integers are then compared to N_a and N_b to determine whether orders are available for matching. In other words, if $N_a = j$ and $N_b = r$, it signifies that all the orders have been successfully matched.

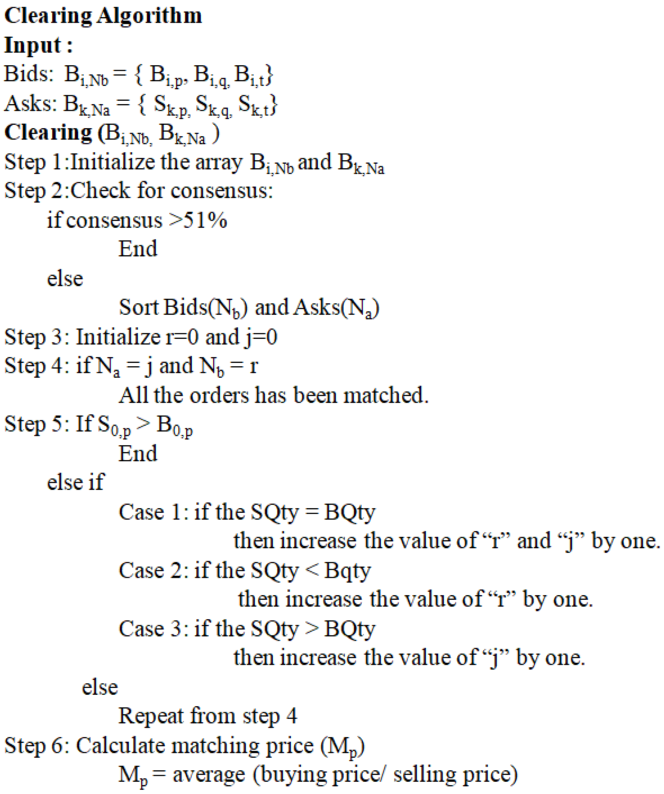
If $N_a \neq j$ and $N_b \neq r$, the price comparison is carried out by selecting the first element from the sorted arrays. If $S_{0,p} > B_{0,p}$ within the sorted array, the process terminates. Otherwise, a comparison is made between the quantities of bid and asks orders, which is categorized into three cases:

Case 1: if the SQty = Bqty then increase the value of “r” and “j” by one.

Case 2: if the Sqty < Bqty then increase the value of “r” by one.

Case 3: if the Sqty > Bqty then increase the value of “j” by one.

In all three scenarios, the matching price (M_p) for the energy is calculated as the average between the buying price and the selling price. The buyer first transfers the M_p-related Total Energy Credit (TEC) to a provisional clearing contract account. After the energy transmission, an equivalent quantity is then sent to the seller via the token settlement procedure. This entire transaction is recorded within the local energy trader's account. This sequence continues until either the selling price surpasses the buying price or until all the orders have been successfully matched. In the event that a single buyer matches with multiple sellers, their respective buying quantities are aggregated under the label 'Bqty.' Similarly, if a single seller matches with multiple buyers, the selling quantity, along with the corresponding price, is incorporated into an array.



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Clearing Algorithm
Input :
Bids:  $B_{i,Nb} = \{ B_{i,p}, B_{i,q}, B_{i,t} \}$
Asks: $B_{k,Na} = \{ S_{k,p}, S_{k,q}, S_{k,t} \}$
Clearing ($B_{i,Nb}, B_{k,Na}$ )
Step 1:Initialize the array $B_{i,Nb}$ and $B_{k,Na}$
Step 2:Check for consensus:
    if consensus >51%
            End
    else
            Sort Bids($N_b$) and Asks($N_a$)
Step 3: Initialize r=0 and j=0
Step 4: if $N_a = j$ and $N_b = r$
            All the orders has been matched.
Step 5: If $S_{0,p} > B_{0,p}$
            End
    else if
            Case 1: if the SQty = BQty
                        then increase the value of “r” and “j” by one.
            Case 2: if the SQty < Bqty
                        then increase the value of “r” by one.
            Case 3: if the SQty > BQty
                        then increase the value of “j” by one.
        else
            Repeat from step 4
Step 6: Calculate matching price ($M_p$)
            $M_p$ = average (buying price/ selling price)
```

Fig 3. Clearing Mechanism

During the exchange of energy, the smart meter gateway sends the energy measurements of consumers and prosumers to the blockchain network through BC-SM by energy traders every minute. The smart contract checks whether it is time for mining rewards. The smart meter initializes the token for energy consumed or produced, and to accept the clearing mechanism of the energy market by the participants, it digitally signs the consensus and updates the transaction timestamp. Subsequently, both the owners account and microgrid account are revised.

D. Rewards

During energy trading, participants (both prosumers and consumers) will get rewards for P2P energy trading during the settlement process [15]. This section explains how token settlement is done for both prosumers and consumers.

Consumer Settlement: During consumer settlement, the buying quantity is determined and the settlement is made based on four cases: First, using the public utility selling price, the whole energy cost equivalent of the utilized energy in the consumer account is transferred to the public utility account if Bqty = 0. Second, If Bqty = Consumed Energy, the consumed energy and buying quantity are reboot to zero. Third,

If Bqty > Consumed Energy, to calculate the total energy cost corresponding of the surplus energy the customer purchased but not used, the purchase price of public utility is applied, which is lower than the initial price. This act as a retribution for making purchases that exceed consumption. At the time of the subsequent settlement, the public utility gives this total energy cost equal to the client. Additionally, the amount of energy purchased and used is set to be zero. Fourth, If Bqty < Consumed Energy, Using the more expensive public utility selling price, the whole energy cost equal of the quantity used that the client wasn't able to purchase on the energy market is moved from the account of the user to the public utility account. The procedure is then finished and the amount of energy that was purchased and used was set to zero.

Prosumer Settlement: This settlement is done for prosumer who produce electricity during the current time slot after the consumer settlement. The two following case studies are employed to assess the energy generation of each prosumer for all the customers and/or prosumers they were paired with in the most recent energy market clearing. In the first scenario, where Produced energy exceeds Sqty, the surplus energy is reduced by Sqty, and an amount equivalent to Sqty in total energy credit is shifted from the account used to clear contracts to the prosumer's account. In the second scenario, when generated energy is less than Sqty, The energy generated causes the clearing contract account to send the entire energy credit equivalent to the prosumer's account. Using the variance between the public electricity and prosumer selling prices, the energy comparable of the prosumer deficit (Sqty - Produced energy) is also transferred from the prosumer's ledger to the public electricity ledger. The prosumer will pay a penalty for not providing the matching energy since the public utility supplied it.

These actions are executed a total of 'sellcount' times, corresponding to the number of instances when a producer was paired with a buyer during the most recent energy market clearing period for energy trading. The prosumer is also assessed at the conclusion of the loop to see whether the amount of energy generated is greater than zero. In this instance, prosumers create more than they did during the previous T, the clearing of the energy market. If this is the case, the public utility buy price is used to determine the TUM Energy Coin equivalent of the extra energy generated. During the subsequent token settlement, the public utility gives the prosumer this total energy credit equivalent. The procedure will thereafter come to a conclusion. This allows energy producers to get a certain quantity of total energy credit in exchange for the energy they supply to the microgrid.

IV. **Simulation**

The proposed system has been simulated for 24hrs having 72 households with six different microgrid scenario. Table 1 shows the different scenario, participants, clear mechanism and auction bidding price range. Initially reference scenario is considered where no biding is carried out. The prosumer generates surplus electricity and provides it to the utility at an approximate rate of Rs 3.61 per kWh, while all consumers purchase electricity from the utility at a rate of Rs. 6.19 per kWh. The auction process considers two price range scenarios: a narrow range (NR) and a broad range (BR).

In the narrow range (NR), consumers initiate the auction by bidding for electricity starting at Rs. 4.5 per kWh and incrementally increasing their bid price by Rs. 0.4 per kWh if they do not secure all the required electricity in future auctions. Prosumers within the same range of prices begin by charging Rs. 5.20 per kWh and then progressively reduce it by Rs. 0.4 per kWh. If the bid is unsuccessful, the prosumer then begins with an initial asking price of Rs. 6.19 per kWh and reduces it by Rs. 0.4 per kWh for subsequent unsuccessful attempts.

Scenario	Participants	Clear Mechanism	Price Range
Reference	Various	No auction	-
3C5P	3 consumers 5 prosumers	DiP	NR
5C3P	5 consumers 3 prosumers	DiP	NR
5C5P	5 consumers 5 prosumers	EqP	NR
5C5P	5 consumers 5 prosumers	EqP	BR

Table 1: Scenario, Participants, Clear mechanism and Auction bidding

Smart Meter Gateway (SM) and Home Energy Management System (HEMS) are represented by two different Python scripts. The Python script for the SM had the responsibility of transmitting daily consumption data per minute to the BC network. The Python script for Home Energy Management System (HEMS) had the responsibility of generating energy consumption forecasts for future usage. It was also responsible for generating and submitting requests and bids to the Blockchain (BC) network. Initially, every consumer and prosumer received a total energy credit (TEC) amounting to Rs. 100. To monitor the performance of each microgrid scenario, for each log, a Python script was written to continually log and record output information using the Blockchain network over a minute-by-minute basis. Each user's TEC balance, energy created, energy spent, buy quantity (Bqty), and sell quantity (Sqty) were all recorded. Additionally, the charges for transactions between users and the deployment of the Smart Contract (SC) to the network were determined. There were twenty-four hourly periods available for the simulation to run in. As a result, throughout the course of the 24-hour simulation period, the market was cleared on an hourly basis.

V. **Result**

The results of the simulations mentioned in Section IV are presented and examined in this section. Figure 4 illustrates the charts depicting the energy production and consumption (top graph - Fig. 4a), the total cumulative energy (central graph - Fig. 4b), and the balance of the Total Energy Credit (TEC) (lower graph - Fig. 4c) for Prosumer1 in the exemplary case. Constructive energy indicates consumption, whereas adverse energy signifies an injuction of surplus energy. According to Fig. 4(top graph), Prosumer1 initiates energy imports from the microgrid at 12:00 am (0 min) and continues until approximately 5:22 am (322 min). Afterward, it transitions to exporting energy to the microgrid until around 4:40 pm (1000 min), after which it resumes importing energy. Regarding Fig. b (middle graph), the cumulative energy chart exhibits a steady linear increase starting from 12:00 am (0 min) and continuing until approximately 6:05 am (364 min).

Comparing the three plots in Fig. 4, we observe the following patterns for Prosumer1:

- When Prosumer1 draws energy from the micro grid, reflecting energy consumption, its total energy credit balance experiences distinct decreases.
- Simultaneously, the accumulated energy steadily increases during this period.
- Conversely, when Prosumer1 supplies energy to the micro grid, indicating energy production, its total energy credit balance undergoes distinct increases.
- During this export phase, the accumulated energy decreases.
- There is a significant time interval (210 - 410 min) during which the total energy credit balance (as shown in Fig. 4 bottom graph) remains almost constant. This shows that Prosumer1 does not engage in energy

exchange with the micro grid during this time and produces almost all of its energy needs on its own.

- The patterns shown in Fig. 4(lowest graph) include a total of 24 steps, which match the amount of time slots and token settlement frequency that prosumer 1 experienced throughout the experiment.

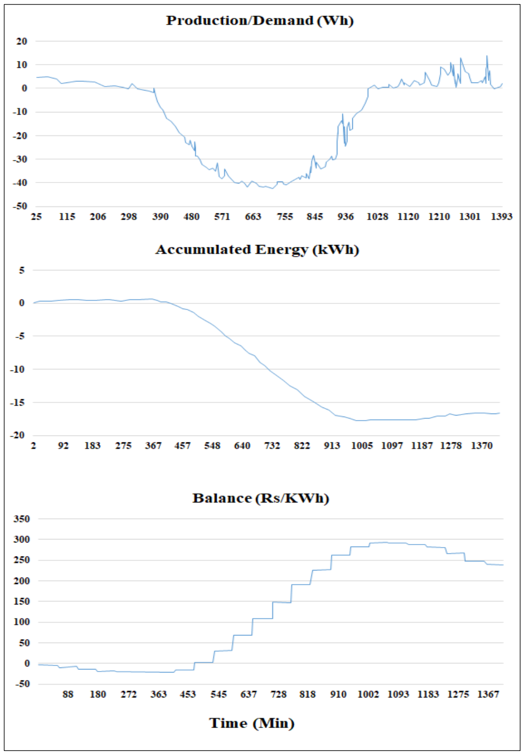

Fig 4. Real time prosumer output information for reference situation

Real-time charts of Consumer1's actions in the example situation are shown in Fig. 5: Consumer1 constantly uses electricity from the micro grid throughout the day, as seen in Fig. 5a. The greatest energy use is seen between 9:10 am and 12:05 am (545 and 700 minutes, respectively). According to Fig. 5b, the cumulative energy exhibits a nearly linear increase from midnight (0 minutes) to 9:04 am. Up until 11:50 am, it then continues to rise incrementally before beginning to rise again virtually linearly. Consumer1's TEC balance drops incrementally in Fig. 5c from 12:00 am to 09.50 am (580 min). Up until 11:47 am (707 min), there is a greater decline; after that, it declines gradually. The times of high consumption exhibited in correlate to this decline in the TEC balance.

Comparing these three plots (Fig. 5), we can draw the following conclusions:

- As Consumer1 uses electricity, its total energy credit balance gradually declines while the stored energy almost doubles.
- The peak load, which was seen between 9:05am and 11:40am, is what caused the step rise in total load. The peak load usage is what causes the TEC balance to decline more quickly at this time.
- Every hour, token settlements cause decreases in the TEC balance, which are shown as step functions and are steeper during peak load hours.
- The entire time allotted for Consumer1 during the simulation, as well as the frequency of token settlements are shown in Fig. 5c together with a total of 24 steps.

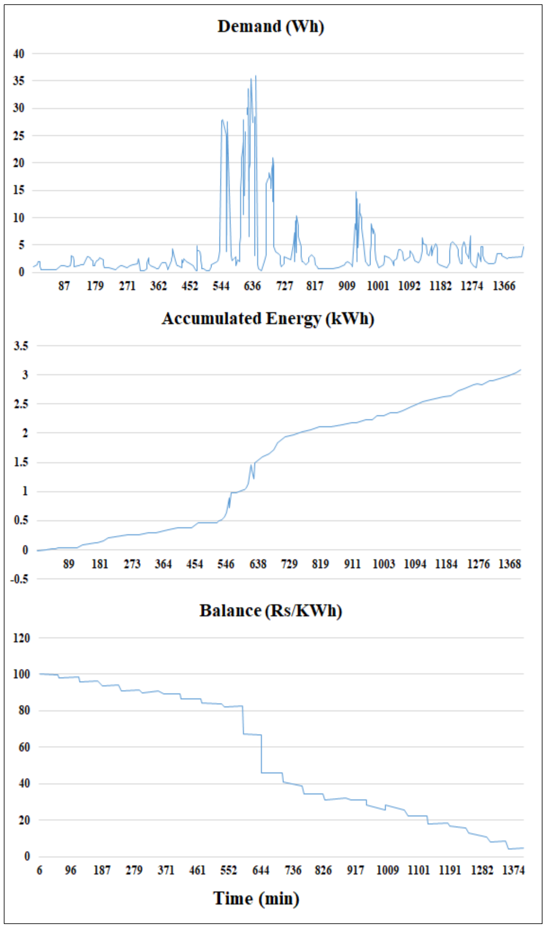

Fig. 5 Real time consumer output data for reference situation

The blue plot in Figure 6 represents the reference scenario. The charts show real-time consumer1's Total Energy Credit (TEC) balance in six alternative microgrid scenarios. From these graphs, several observations can be made:

- From 0 to 184 minutes, every graphic shows the same pattern. Consumer and prosumer bid and ask pricing have not yet attained market equilibrium during this time period. Therefore, everyone involved purchases and sells energy to the utility.
- At 185 minutes, market clearing occurred as a result of market equilibrium being established between the bids and offers for the 3C5P (NR), 5C3P (NR), 5C5P (NR), and 5C5P (BR) scenarios. As a consequence, customers' accounts were debited by an amount of total energy credit equal to the matching energy quantity. Even if the energy that is purchased is meant to be used in the future (between 307 and 1158 minutes), customers nevertheless pay the utility on an hourly basis until 307 minutes. The two-step reduction in the total energy credit balance of consumers for these four situations, from 185 to 307 minutes, is indicative of this.
- For these four situations, the customers' TEC balance remains almost unchanged between 307 and 1158 minutes. Customers do not have to make payments again during hourly token settlements if they have previously purchased energy for this period.
- For these four circumstances, the TEC balance of consumers starts to go down gradually about 1158 minutes. This is due to the fact that customers had to purchase their energy from the utility at this time since prosumers were not producing energy. Given that consumer purchase energy from

the utility at the same cost, the step decline is comparable for these four scenarios.

- In contrast, the 5C5P (BR) scenario's bids and asks attained market equilibrium at 550 minutes because of a broader price range, delaying market clearing. At this point (550 minutes), additional TEC-equivalent reductions were made to match the energy. The consumer's TEC balance does not change from 550 to 1158 minutes due to the energy acquired during market clearing.
- Similar to the reference scenario, the 5C5P (BR) scenario's TEC balance for the customer starts to decline gradually after 1158 minutes since the consumer purchases energy from the utility for this period of time, paying for it on an hourly basis.
- The plots imply that consumers who can get a smaller bidding range may be able to make money. Additionally, it is evident that consumers can earn more from peer-to-peer (P2P) trading with prosumers than from dealing with the utility.

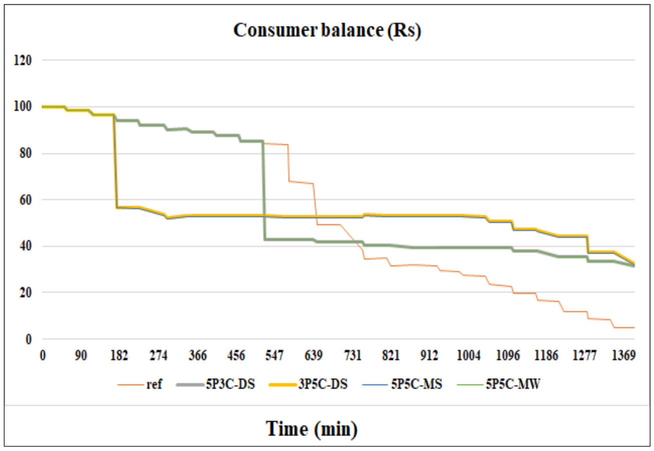

Fig 6. Balance of consumers in various microgrid situations

In Fig 7, the charts illustrate the real-time Total Energy Credit (TEC) balance of Prosumer1 within six distinct microgrid scenarios. These plots reveal the following patterns:

- The TEC balance of Prosumer1 follows a consistent step-wise decrease pattern from 0 mins to 427 mins across all scenarios. During this time interval, the prosumer buys energy from the utility, resulting in hourly payments. These payments are reflected as step decreases in the TEC balance during token settlement.
- From 427 minutes to 1154 minutes, the total energy credit balance of the prosumer increases in steps for all scenarios. The step increase is more pronounced in scenarios with auctions compared to the reference scenario. This is because in these auction scenarios, the prosumer engages in direct trading with consumers, leading to higher profits compared to trading with the utility.
- After 1154 minutes, the prosumer's TEC balance experiences a consistent, step-wise decline across all scenarios. In this timeframe, the prosumer draws electricity from the utility and settles their consumption charges on an hourly basis using tokens.
- The overall conclusion is that it is more profitable for a prosumer to engage in peer-to-peer (P2P) trading with consumers rather than trading with the utility. This is evident from the higher profits achieved in scenarios where direct trading with consumers is facilitated.

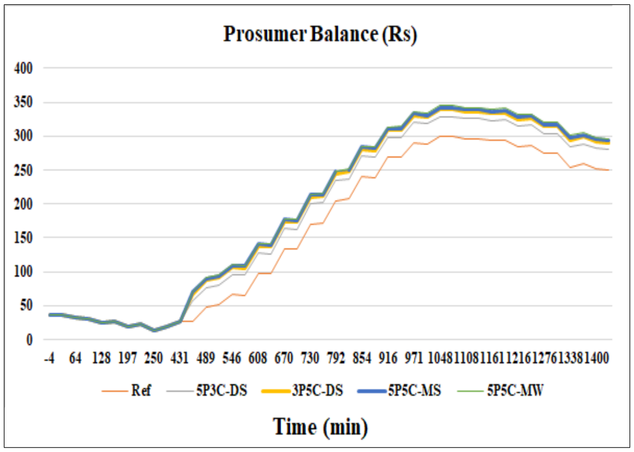

Fig 7. Balance of prosumers in various microgrid situations

"Gas" is the term used to measure the amount of computational cost associated with a certain transaction in a blockchain (BC) network [11]. In the context of deploying the P2P Energy Smart Contract (SC), the transaction incurs a cost of 19,896,454 gas, surpassing the predefined gas limit for transactions on the public Ethereum network, which stands at 8,000,000 gas. This implies that deploying the SC on the public Ethereum network is essentially unfeasible without an increase in the network's gas limit. Moreover, the expense linked to transmitting consumption and production data to the BC network every minute amounts to 67,369 gas. When converted into Ethereum (ETH) at the prevailing exchange rate from [12], this translates to approximately 270.2 ETH. Thus, it is not economically feasible to deploy this paradigm for local energy trade on a public BC network that is extensively used, such as Ethereum. A public BC network consortium that provides lower transaction costs appropriate for energy trading is required to overcome this problem.

VI. **Conclusion**

In this paper, a product design, a sequence of events, and algorithms designed for the automation of energy trading through smart contracts was presented. The functionalities of Home Energy Management Systems (HEMS) and Smart Meter Gateways (SM) for prosumers, consumers, and utilities are utilized. Through simulations carried out across different microgrid setups, we have validated the feasibility and effectiveness of the peer-to-peer (P2P) energy market implemented on the blockchain network. The primary conclusions drawn from this research can be outlined as follows:

- Prosumers and consumers benefit from higher profits when engaging in electricity trading with each other rather than trading with the utility.
- To facilitate peer-to-peer (P2P) energy trading on a blockchain, the involvement of blockchain operators or consortium authorities is necessary. This includes tasks like updating smart contracts, adding new participants, and transferring initial tokens.
- The current high gas costs on the public Ethereum blockchain network make it economically unviable for electricity trading.
- A closer bidding range in a P2P energy market increases the likelihood of generating a profit for participants.

Author Contribution

G. Divya: Investigation, Methodology, Writing - original draft. P Supraja: Conceptualization, Formal analysis, Writing - review & editing.

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