Efficient renewable energy management using Blockchain technology

by

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B.Sc. in Computer Science and Engineering

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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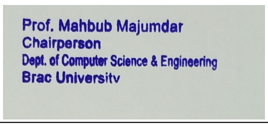

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Abstract

Smart grids lay the groundwork for future cities. In our daily modern life we use many intelligent devices such as smart offices, smart buildings, smart streets, and smart houses etc. All of them should be supplied by a smart energy service in order to achieve full capacity.In its application to energy infrastructures, Blockchain has several possible benefits for Usage of energy optimally and in real-time, monitoring and trading. To help us with our ever-growing demand for clean energy resources. This research work represents a blockchain-based virtual smart grid. A smart grid fitted with smart contracts is assessed and potential strengths and drawbacks are addressed, capable of carrying out virtual operations. This research work insists on developing a blockchain based smart renewable energy service with the help of Ethereum based blockchain network.

Keywords: Blockchain; Ethereum; Renewable energy; Smart contracts; Smart grid; Hyper Ledger; Ganache; Metamask; Remix IDE; Json.

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Chapter 1

Introduction

Often known as Distributed Ledger Technology, Blockchain is basically a chain of blocks. It makes the history of any digital resource unalterable and transparent by using decentralization and cryptographic hashing. Almost every blockchain is made of of three significant parts: blocks, nodes and miners. One of the most encouraging aspect of blockchain is that it permits us to share important information in a protected, tamperproof manner by decreasing risk, stamping out fraud and bringing transparency in a scalable way for the general users. As a result, blockchain technology is now being implemented in large number oif industries and enterprises. And likewise many companies in the energy sector are already starting to implement blockchain technology in their system as well for more sophisticated outcomes. However, there are few issues and shortcomings we need to acknowledge before implementing blockchain technology in the energy sector [4]. Energy resources such as

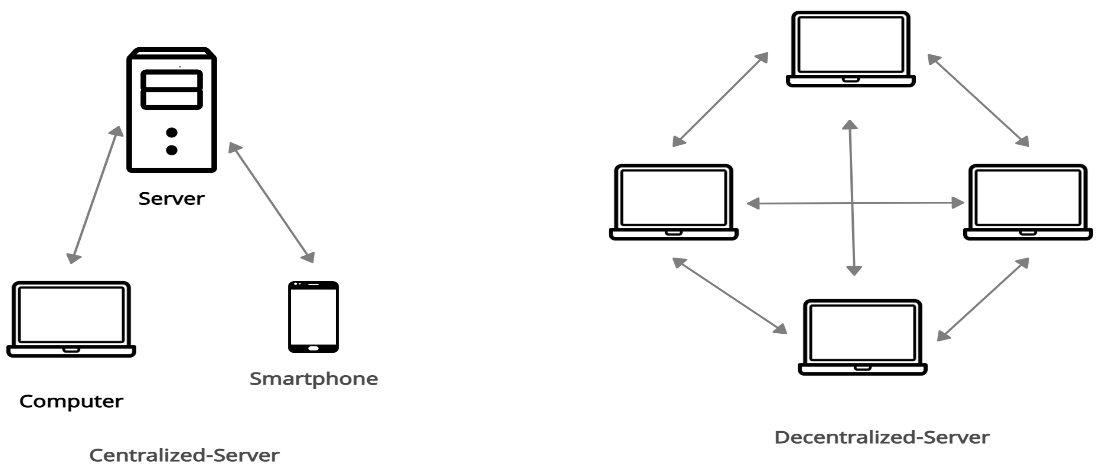

Figure 1.1: Database vs Blockchain

water, gas, electricity etc. are the driving force behind any manufacturing and production that takes in modern world. In almost every economic and social growth, these are important services that play a critical role.A requirement for successful poverty eradication is quality infrastructure and steady energy supplies. But the global energy landscape is changing fast.We are gulping these valuables at an exponential rate as customers, from basic survival all the way to luxury, even. By now, it should be clear that we're already close to consuming more than we can produce or deliver, which becomes clearer when peak utility demands are maximum during seasonal rushes. The problem is that we add more demand, legally and illegally, for these precious products than we add ability to generate them [1].

To deal with this growing demand we can try to expand our productions. But expanding energy production may seem much complicated than it looks. To facilitate the expansion billions of dollars in funding might be needed. As well as lots of serious decisions, city planning programs, and environmental costs, etc. are needed to take into consideration. Therefore, making such investments, such as resource generation and distribution, a slow, long-term proposal, has fallen well below the growth in GDP in most developed countries. [2]. Even though, we continue to face the problem of energy consumption. We cannot simply ignore the fact that many of the energy sources contribute to numerous environment related problems. For example,When fossil fuels are burned, nitrogen oxides are released into the atmosphere, contributing to smog and acid rain. Due to rapid urbanization and unplanned industrialization our mother nature is getting affected very badly. Even though, most of the energy sources have some effect on the nature. But fossil fuels like coal, petroleum, natural gas, oil do considerable amount of damage to our environment than renewable energy sources. As a result, global warming emissions are happening, public health are getting affected, wild life and habitat are getting lost, air and water are getting polluted day by day [4].

So, day by day it is becoming more evident to us that we should rely more on renewable energies for better sustainable development and cleaner environment. Renewable energy diversifies our supply of energy and reduces our reliance on imported fuels. It paves a new way for economic development by creating jobs in manufacturing, installation, and more. It stabilizes our energy expenditures, as price changes do not impact renewable sources of energy. When you can sell electricity at a premium back to the grid. It can be another source of revenue. The management of your energy usage and needs is more manageable, simpler. It allows us to reach carbon reduction goals. It strengthens our credibility as clients and partners appreciate their contribution to sustainability. The exemption from the Global Warming Tax (a government-imposed tax designed to encourage energy efficiency and carbon emission reduction among businesses) [3]. However, the volume of renewable energy such as solar heat, wind, sunshine, wave etc. are above human interference. If the amount of power generated is minimal, a reliable power plant can be operated to compensate for any shortfall. However, it is hard to deal if the quantity produced is too high. There is no space for blockchain technology to be implemented into the energy sector in this case. Also there are drawbacks to the use of renewable energy of this nature. Because there are shortage of government policy regarding this field.There is a shortage of infrastructure and technology to check our country's use of renewable energy [4].

As blockchain information is largely stored in thousands of computers on a distributed network of nodes, the system and data are highly resistant to technical failures and data theft. As a consequence, no single failure point exists. The network's availability or protection is not compromised by a single node going offline.

Blockchain is often regarded as a temper proof technology.Confirmed blocks are very unlikely to be overturned. After data has been registered in the blockchain, removing or modifying it is exceedingly difficult. It enables Blockchain a perfect technology for storing business information because any change is permanently monitored and registered on a distributed and public ledger. Moreover, because this distributed network of nodes verifies transactions through a process known as mining, there is no need for transaction verification by an intermediary. Thus, a blockchain framework negates the danger of trusting a single entity and also decreases the total costs and transaction fees by cutting out intermediaries and third parties. [5]. Because of its environmentally friendly nature, renewable energy is gaining more popularity day by day. In the energy field, different types of blockchain implementations are now used. Such as the use of energy data, peer-to-peer power trading, sharing of energy, charging and sharing of electric vehicles and so on. The most popular type of energy blockchain among these types is P2P (peer-to-peer) electric power trading. The value chain of the energy sector will adjust accordingly if the blockchain is introduced into the energy market. Via the use of the blockchain, the latest peer to peer business model would allow renewable electricity to be exchanged between individual buildings.It will decrease transaction costs and provide precise records of transactions. The transition from a centralized energy trading model to a blockchain-based distributed energy trading model would decrease the role of the central government, which has so far acted as an intermediary for power trading. The number of energy prosumers will also be increased [4].

The blockchain framework executes the transaction process in the following ways. The transaction data is shared to all the nodes in the blockchain over the network when a transaction takes place between trading partners. Next, blockchain participants who have obtained the transaction data decide if the encrypted transaction data is a legitimate transaction by mutual verification. Then, the approved transaction data is stored in a new block and associated with an existing block of transactions. Finally, transactions and contracts are concluded between the parties. The key difference, however, is that there is no 'Trusted Third Party' to ensure trust between a network of blockchains and a traditional system. In the blockchain-based environment, transaction data is transferred to the P2P (peer-to-peer) network. So that, transaction details can be jointly documented and handled by the participating members. Therefore, the expertise and assets required for the development and functioning of a third party are not essential [3]. But many of the blockchain driven systems in the energy fields are poorly managed and designed. Traditional blockchain technology lacks efficiency, features,Consistency, safety. Therefore, we intend to apply blockchain technology in this paper to an open and equitable energy management framework by measuring Renewable and new energies. We suggest a fairly efficient consensus algorithm among block-chaining techniques and through various simulations and computations we will implement the proof of work algorithm [2].

So, in this paper we will try to build an effective smart renewable energy service using the ethereum blockchain with the help of smart contracts, ganache, metamask and solidity [5].To sum up, new and renewable energy is confirmed by the technologies presented in this report. In addition, this study suggest a new model for the conclusion of intelligent contracts between renewable and alternative energy suppliers and customers and the use of sustainable energy verification blockchain technology. Here, there is a significant effect on future transaction efficiency of the appropriate consensus algorithm. Therefore, main blockchain technologies will be introduced in the future. Figure 1 is also a network that uses electricity blockchains using P2P services, smart meters, and solar power. It is an intelligent grid that uses solar light to capture energy in each individual house and distribute the energy to each other next households; this is referred to as a micro grid. However, a blockchain is used as a method to verify intermediate collection and processing of sunlight.

Chapter 2

Literature Review

the research and works in relation to blockchains and energy trading have been performed by the following Researchers. Subhasis Thakur and John G Breslin released their research contributions "peer to peer energy trade among micro grids using blockchain based distributed coalition formation method" and with Barry Patrick Hayes they also worked on "co-simulation of electricity distribution networks and blockchain energy trading platforms". Meanwhile, Jun-Ho Huh and Seong-Kyu Kim worked on developing a viable consensus algorithm for peer to peer energy blockchain trading. They presented their work under the title of "the blockchain consensus algorithm for viable management of new and renewable energies". Other informative works include "implementation of blockchainbased energy trading system"(Se-Chang Oh, Min-Soo Kim, Yoon Park, Gyu-Tak Roh and Chin-Woo Lee). A novel decentralized platform for peer-to-peer energy trading market with blockchain technology (Ayman Esmat, Martijn de Vos, Yashar Ghiassi-Farrokhfal, and Peter Palensky Dick Epema).

2.1 Renewable Energy

Renewable energy is a sustainable form of energy which can be used to preserve the local resources of the Planet, which are increasingly falling victim to climate change. It includes the energy produced by the use of daylight, water, rainfall, microbial substances, etc. bio , wind, solar and hydro provide renewable energy sources. Novel power sources are fuel cells and hydrogen energy[4].
Solar energy is generated using solar power generation systems by transforming sunlight to electricity. The first kind of solar power generation system is referred to as a grid system. Energy is generated by connecting generated electricity to the grid of a power company. The other sort of system includes grid power networks, autonomous construction methods such as satellites, lighthouses and developments in construction supplies that are not electricity. Next one is a blended system consisting of solar power and diesel power or the production of wind power and solar power.Solar thermal energy is a system in which water gets heated using solar panels and, by capturing, retaining and transmitting energy from the sun is used for cooling and heating buildings. A solar thermal system is composed of a heat gathering unit and a heat storage unit. It is widely used for the supply and heating of indigenous hot water as it is inexpensive and easy to install[4].

Wind energy is a mechanism that transforms wind energy into electrical energy from kinetic energy. Airflow flips the turbines of a windmill and uses a generator to generate electricity. Through distributing it to a power utility, It is plausible to use the resources directly, that is produced or to sell energy. The following elements consist of the wind turbine system. Windmill blades are used to transform the wind's kinetic energy into rotational mechanical force. In the most powerful way possible, the gearbox amplifies the torque. Hydraulic tilting energy is converted into electrical energy by the generator. The energy converter transforms the generated direct current from the generator into alternating current that can be used in Households [2].

Hydrogen energy cell is a device that, by electrochemical reaction, transforms chemical energy from hydrogen fuel into electric energy. Using a continuous fuel supply, it can continuously generate electricity without recharging. Sewage is produced by the heat generated during reactions. Reformer is a tool which transforms methanol, natural gas, petroleum, coal, etc. into hydrogen fuel, is part of the fuel cell power generation system. The generator generates hydrogen electricity and has an inverter for fuel.The Recycling Device for Waste Heat accumulates the created excess heat and uses it for heating water [4].

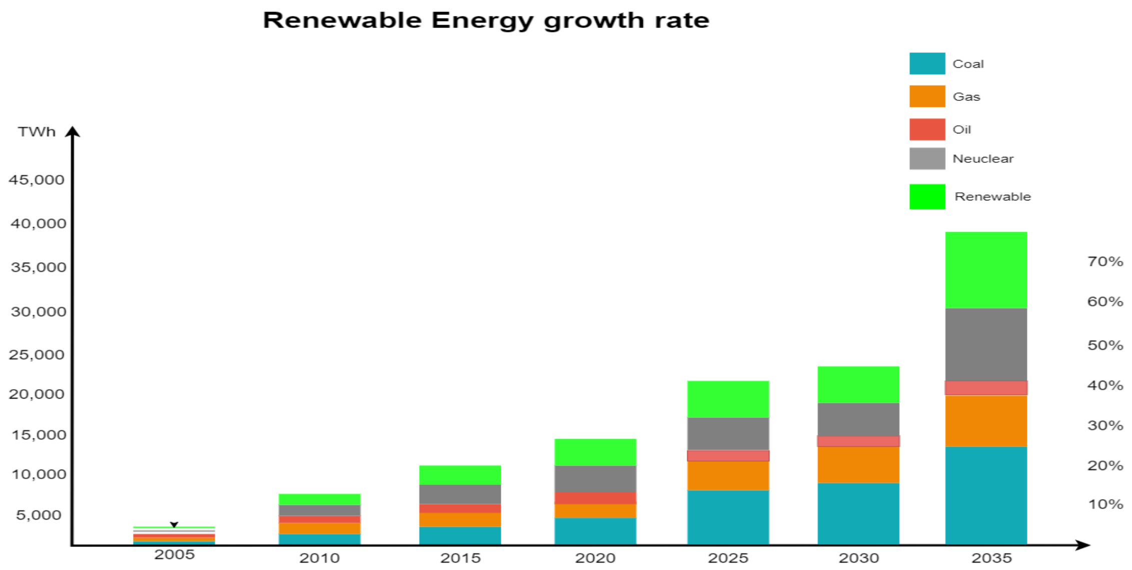

Figure 2.1: Renewable energy growth rate

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duced by the heat generated during reactions. Reformer is a tool which transforms methanol, natural gas, petroleum, coal, etc. into hydrogen fuel, is part of the fuel cell power generation system. The generator generates hydrogen electricity and has an inverter for fuel.The Recycling Device for Waste Heat accumulates the created excess heat and uses it for heating water [4] The utilization of energy through biological processes to acquire liquid fuel from agriculture is bioenergy. A processing method of bio-energy extracts methane gas by using Biological excess and uses a turbine to generate electric energy. burning industrial excess, by generating steam from burning excess heat, steam generation heat and contamination control systems include waste energy systems. Geothermal energy corresponds to the Earth's heat energy from the surface to the subterranean, which is carried out and utilized by a building's heating and cooling device. By using the planet's chilly temperature in summer and the Planet's hotter temperature in winter, energy is produced. Hydropower is a device that, using falling water, produces electricity by flipping the turbines attached to a generator [7].
Hydropower production of 10000000 watt or smaller per module is called small-scale hydropower production and, in addition to electricity generation, can be used to agrarian water repository sites, water filtration plants, sewage treatment units, etc. Ocean energy comprises wave energy, wave energy derived from arising and dropping water magnitudes, and sea water heat differential power using the heat difference among deep and surface water. It is possible to apply this renewable energy to different industries. Furthermore, if the blockchain mechanism is being used to more open and distributed facilities it will be used to more trust-based energy related blockchains. Latest and green power will be explored and applied through the globe for peer-to-peer business oriented pilot projects in the future. However, a side effect occurs where the confirmation of the usage of green energy is not carried out in a transparent manner. We suggest a consensus algorithm in this paper that utilizes blockchain as a tool to eradicate these issues and also needs considerable performance information that will be of interest to lot of people in the coming days.[4]

2.2 Blockchain Technology

Blockchain is a key mechanism that will eliminate centralization issues and further diversify the current centralized dealing scheme as it expands to new business platforms. There is a minimal security mechanism in current intermediary or assured peer to peer convergence-based economic and electronic dealings that can be problematic to all peers in the event of central organization problems. In addition, in The occurrence of error of the central entity. The centralized service must stop the whole system; on the other hand, the blockchain is indefinitely viable until all network members are stopped [11]. The P2P (peer-to-peer) Bitcoin was introduced as an alternative in 2008, while Etherium was launched in 2015, which can introduce different programs such as smart contracts. Furthermore, blockchains are incredibly reliable which could be passed straight without any option to a central organization. As all information is chronologically encoded and connected, old records cannot be forged or altered because all blocks must be regenerated after that point, and every versions of the network's register should be restored. A centralized management system is necessary in current Internet transactions, but this is plausible to deal straight with the users in the blockchain network, it immensely enhances its future applications in the busines sector [8]. Blockchain mechanism is built upon a consensus mechanism, which without a central authority updates the ledger of all network members. It is an mechanism that apply modifications to a blockchain and deciding how to manage changes among network members, like new business dealings information, since they have multiple privileges for writing. Blockchain relies on mathematical theories such as ledger correcting algorithms for all nodes when new data is received. Created to avoid multiple payouts, Fraudulent exploits and

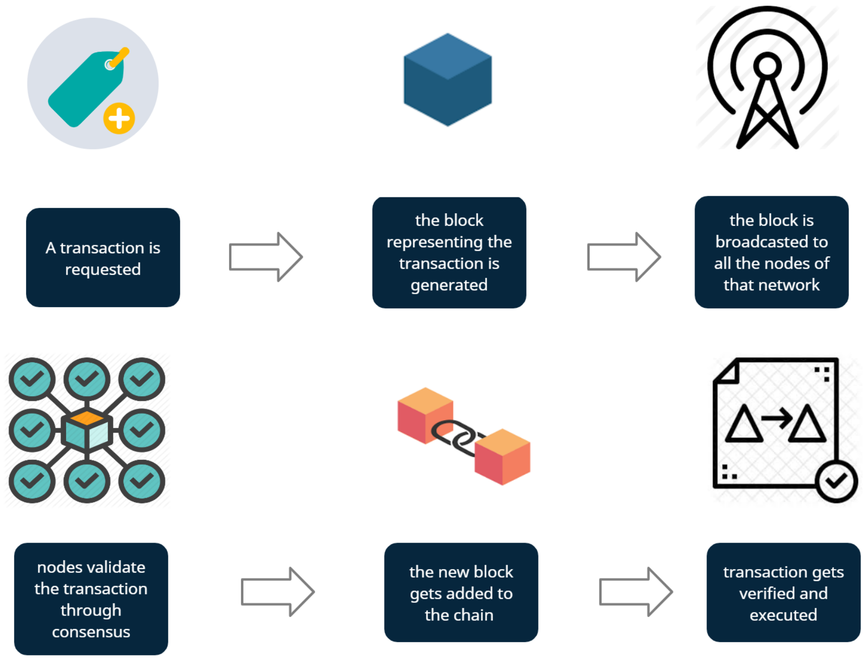

Figure 2.2: Blockchain architecture

algorithms for prevention. For example, there is no P2P-based communication issue in a situation where a general does not recognise a traitor, in that unraveled generals do not have central authority in a way that, despite the information disruption of the betrayer, they can agree on a common activity. It is figuratively clarified. For about 30 years, these ideas have been studied and the Functional Byzantine Fault Tolerance (PBFT) and Proof of Work (PoW) methods are basically the foundation for the creation of a blockchain that is permissive [4] [10].

2.3 Different kinds of Blockchain

Blockchains have been classified into three groups:

1. Public blockchain
2. Private blockchain
3. Consortium blockchain

based on the use and requirements. - Of these blockchain networks serves its function and addresses unique issues, and over each other, each blockchain has its own set of features and benefits. Let's start with the blockchain most widely recognized, i.e., the public blockchain [3].

2.3.1 Public blockchain

A permission less, non-restrictive, distributed ledger system, this blockchain means that everyone linked to the internet will enter and become part of a blockchain network. The fundamental use of such a blockchain is for the distribution and mining of cryptocurrencies. In addition, it maintains trust among the entire user group as everyone in the network feels empowered to work towards enhancing the public network. The first example of such a blockchain is Bitcoin, which enables transactions to be carried out by all. Examples of a public blockchain also include Litcoin and Ethereum [19].

2.3.2 Pros of public blockchain

- For any kind of network, trust is a more fundamental element. More trust is provided by the public blockchain.
- All data and information is publicly documented in full. So it is not possible to modify or change the details.
- It inspires individuals to do the right thing to enhance the network.
- No need for intermediates or third parties.
- It is thoroughly decentralized. So it offers coverage at the high end.
- More individuals operate on this network, so hacking the data and information is very difficult for attackers.
- Banding together and taking power of the network is difficult for malicious individuals.
- Anyone can write, join, and engage in the network here.

2.3.3 Cons of public blockchain

- Issues with scalability
- Lack of Speed of Transaction
- Takes up a lot of energy

2.3.4 Private blockchain

in contrast to public, a private blockchain is a permit that runs in a closed network and is a restrictive blockchain. In an enterprise where only specific members are members of a blockchain network, such blockchain is mainly used. For corporations and companies who choose to use blockchain only for internal purposes, it is ideally suited. The main difference between blockchains is that it is highly accessible to the public, while private is limited to a small community of individuals. In addition, since a single body manages the network, a private blockchain is more centralised. The private blockchain examples are Hyperledger Fabric, Hyperledger Sawtooth and Corda [19].

2.3.5 Pros of private blockchain

- It has less participants, so it consumes shorter time to arrive at consensus. The execution time of the private blockchain is high.
- More transactions can occur. Because a thousand transactions per second can be done.
- There are more scalable private blockchains.

2.3.6 Cons of private blockchain

- Because of centralization, the decision-making process is quick. But this is one of the major limitations of a private blockchain.
- In private blockchain, trust is a greater challenge.
- You cannot independently check the records' authenticity.
- Low security scenario.
- Strong possibility of hacking or manipulating data

2.3.7 Consortium blockchain

The blockchain consortium (also known as federated blockchains) is ideally suited for organizations where both types of blockchains are required, i.e. public and private. There is more than one key in-charge in this form, or we can say more than one entity involved that provides access to pre-selected nodes for blockchain reading, writing, and auditing. Since there is no single control body, it retains a decentralized character. Examples of such blockchains are the Energy Web Foundation and the IBM Food Trust [19].

2.3.8 Pros of consortium blockchain

- Best suited for coordination within organizations.
- Provides scalability and highly secure security
- In contrast to public blockchains, more efficient

- Better customizability and resource management

2.3.9 Cons of consortium blockchain

- among major drawbacks of this blockchain one is that it is centralized, rendering it vulnerable to attack from malicious players. Whenever the number of participants becomes limited, one of them is estimated to be at fault.
- The launching process of the blockchain consortium is very sensitive. All the members must give their approval to the communication protocol.
- Less transparent relative to other blockchains and less anonymous

2.4 Blockchain Consensus Algorithms

A blockchain is a decentralized ledger network that passes a complete database server among entities rather than depending on a contractual agreement with a primary control system to preserve the status of the database. The blockchain is, in other words, A sort of book that transmits registers of data about transactions. Each ledger's components should stay same since each node has its own book. However, by using blockchain technology, there is a question of consensus. The consensus algorithm affects many blockchain consensus processes, in which The process of sharing the control of block generation and the process of choosing one chain for producing forks are the most representative. It needs a special certification. Thus, a huge sum of blocks is generated simultaneously if each node can easily build a block without any work, it would make almost impossible for each node to concur on a blockchain. In a blockchain network, each peer gathers transactions for Rather than conducting immediate transaction processing according to the consensus algorithm, for a certain period of time. By choosing a miner who meets a particular context, the block is produced. At this time, different agreement terms, such as the calculation capacity and token holding number, could be the basic condition of the miners needed by each consensus algorithm.

2.4.1 Proof of work

To pick a miner for the following production of blocks, proof of work mechanism is used. This PoW consensus algorithm is used for Bitcoin. The fundamental concept behind this algorithm is to solve and quickly provide an answer to a complex computational puzzle. This computational problem needs a huge computing power and, thus, the node that answers the computational problem will mine the following block as soon as possible [10].

2.4.2 Proof of stake

This is the most common substitute to proof of work. From PoW, Ethereum switched to PoS consensus. Auditors spend in the coins of the network in this sort of consensus mechanism by detaining a few of their tokens as a stake, rather than spending millions in machinery to answer a complex problem. The blocks will start confirming all the verifiers afterwards. By placing a bet on it, validators will check blocks if they find a block which they believe could be added to the blockchain. Depending on the exact blocks applied to the blockchain, all validators receive a reward approximately equal to their bets, and their stake rises accordingly. Lastly, a candidate is selected to build a new block depending on their financial stake in the system. Thus, PoS encourages validators by an opportunity mechanism to enter an agreement[10].

2.4.3 Proof of burn

With proof of burn, rather than spending a huge amount in computational tools ,delivering coins to a location in which they're unrecoverable, auditors burn coins. Auditors obtain a right by committing the coins to an inaccessible address, relying on a random collection process to mine on the system. Therefore, burning tokens here suggests that validators have a lengthy obligation in exchange for their short-term defeat. Depending on how the PoB is applied, miners will burn the own money of the Blockchain implementation or the currency of an external chain, like bitcoin. And the tokens they burn, the higher the likelihood that the next block will be picked to mine them.Although proof of burn is an attractive alternative to proof of work, assets are also expended needlessly by the method. And it is often disputed why mining capacity simply goes to those who are willing to burn more resources[10].

2.4.4 Proof of capacity

Instead of spending a huge amount in equipment or burning coins, validators are expected to spend their storage space in the Proof of Capacity mechanism. The better the odds of having the next block chosen for mining and winning the block reward[10], the more storage space auditors provide.

2.4.5 Proof of elapsed time

proof of elapsed time is one of the soundest implementations for consensus that only uses equivalent means to choose the next block. It is commonly used in blockchain networks that are authorised. Each auditors on the chain gets a reasonable opportunity to build their own block in this algorithm. By having to wait for an unspecified time frame, all the nodes do so, adding proof of the delay to the block. For others, the generated blocks are transmitted to the chain for inspection. The victor is the authenticator in the proof section with the least timer weight. The block is appended to the Blockchain from the victorious auditor peer.In the algorithm, there are more Inspections to prevent users from winning in the selection process every time, preventing nodes from producing the smallest timer magnitude [10].
Other consensus mechanisms also exist, such as Proof of Activity, Proof of weight, Proof of importance, Leased Proof of Stake, Practical Byzantine Fault Tolerance, etc. Therefore, it is necessary to choose one wisely according to the requirement of the business network, as Without consensus mechanisms, blockchain systems do not function adequately to confirm every operation carried out. [10].

2.5 Exisiting Blockchain Implementations

2.5.1 Cryptocurrency

Cryptocurrency is a virtual currency intended for virtual transaction networks that are peer-to-peer. A distributed blockchain element that enables the generation and distribution of currency units. The first blockchain-based decentralized application was digital currency, using the name Bitcoin, which is basically a digital cash form, also known as cryptocurrency. In 2008, an unspecified person using the alias Satoshi Nakamoto was introduced to the concept of blockchain along with Bitcoin. He wrote a research paper on Bitcoin that laid the groundwork for digital crypto-currency systems from peer to peer. Bitcoin and other comparable virtual transaction systems since 2009 in the realm of blockchain technology, they have emerged [5].

2.5.2 Ethereum

Vitalik Buterin proposes Ethereum to counter the Bitcoin Limits. A list of transactions and the most recent state also carry the blocks in Ethereum. In addition to the transfer of funds, Ethereum also guarantees the execution of smart contracts. It makes use of the GHOST protocol to ensure network consensus. This solves the problem of stale blocks that occur when a group of miners have more computing power than the rest and thus contribute more to the network. This would result in the dilemma of centralization. In the longest blockchain measurement, the GHOST protocol combines the Stale blocks. The stale blocks are rewarded, removing the problem of centralization. Even if they have not managed to be a member of the primary blockchain, miners are now rewarded. Ethereum has better block time as opposed to Bitcoin (15 seconds). It has a processing transaction rate of 11 per second. The energy consumption of Ethereum per transaction is estimated to be around 49 KWh. Ethereum offers accounts under the limit of a 160 bit account location size to check the present balance, to deposit or carryout any smart contract. Ether is the virtual currency and smart contracts are independent dealing medimums [1][5]. Smart contract technology runs on Etherium virtual machine to make sure the implementation of the environment for the virtual smart grid. To validate new blocks, the EVM creates complete nodes. Ethereum uses transaction costs, often known as gas usage, to avoid any cyber-attack. In other words, the Ethereum transaction is the volume of gas used multiplied by the gas cost.

2.5.3 SolarCoin

This latest Blockchain application seems exciting because it enables optimization of electrical usage to be accomplished. There is not much information on solarcoin nowadays, but an energy exchange system based on the Blockchain Ethereum6 was developed in Brooklyn in the USA. This device is confined to a microgrid, enabling the inhabitants of the same microgrid to exchange energy derived from solar panels. The producer profits from a SolarCoin for each MWh generated [1].

2.5.4 Hyperledger Fabric

Under the Linux Foundation, the Hyperledger Fabric is a privatized and authorized blockchain[14].The Fabric network was first launched in 2015 as a highly confidential platform wherein users can control, exchange and relate to digitized properties. Fabric was the first one to permit distributed programs coded in regular computer languages to be executed, referred to as chain codes, a piece of code built on the Hyperledger Fabric node network. The architecture of the Hyperledger Fabric consists of the following components: Peer nodes, Endorsing nodes, Node ordering, user implementations. nodes do not restrict themselves to one position. For some forms of transactions, a peer may be an endorser and only a actor for others. The task performed by peers and organizing peers is similiar form of task that miners perform in the different mechanism of the blockchain [5][24].

Chapter 3

System Architecture design & Workflow of the Model

3.1 Blockchain based smart energy supply architecture

Different approaches have recently been proposed to test the efficiency of the smart grid using blockchain. We display the extensive construction of a blockchain-oriented smart energy supply in Figure 3.1.

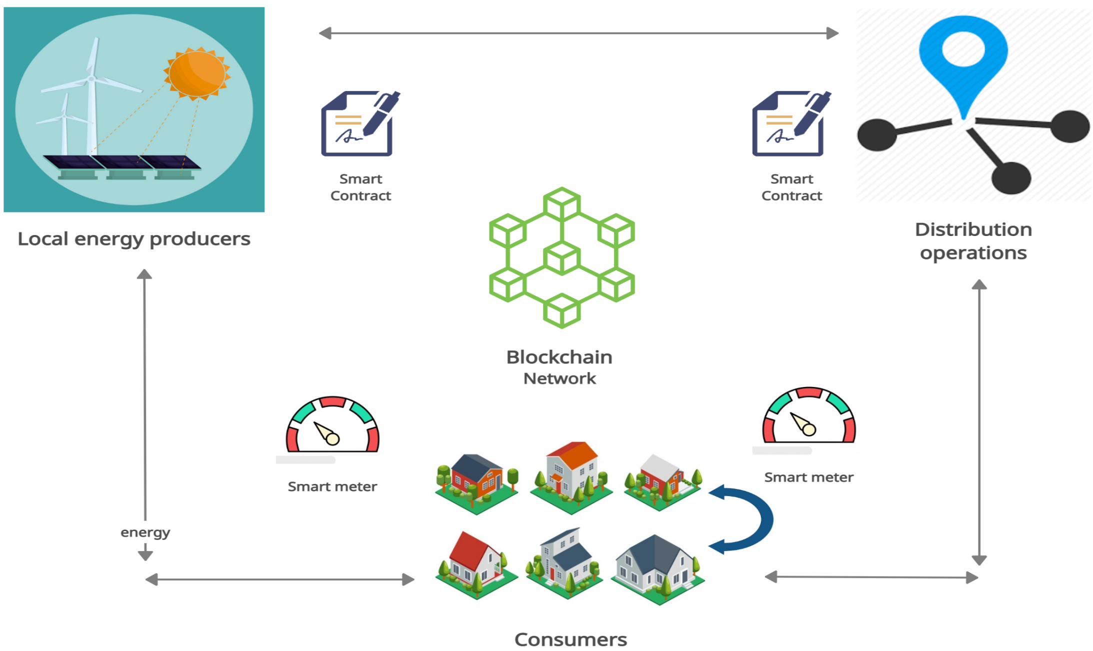

Figure 3.1: Blockchain based smart energy architecture

3.1.1 Distribution System operators

Distribution system operators serve as moderators and are liable for operations such as market processes, customer transaction functions and local energy suppliers. DSOs ensure private data security and the implementation and maintenance of Smart Meters relying on the information from appropriate blockchain accounts (users/producers). To make sure consensus in the energy trade, the DSO functions as a miner [5].

3.1.2 Local energy producers

Nearby energy suppliers produce power and add electricity to the power grid using solar, wind, biogas, etc. Nearby energy suppliers often act as mine workers in the blockchain in order to guarantee agreement and thereby enforce the idea of a distributed financial system. The system is based on micropayment, and the quantity of electricity infused is consequently compensated when certain conditions are met with defined coins using consensus protocol that enable exchanges through the blockchain network[5].

3.1.3 Consumers

In the blockchain layer, users remunerate the market cost and serve as peers. Every house has Smart Meters built. Using intelligent contracts, Smart Meter analysis are registered in the system network. Through defined tokens, users can purchase electricity from either the native electricity supplier or the distribution operators [5][7][9]. Figure 3.1 shows the following steps:

- DSO implements a network based on blockchain, which adds Smart Meters with smart contracts.
- Users use smart contracts to register and build blockchain-based networks and account for them. (using a smart contract)
- Input is transmitted through the blockchain network from the Smart Meter which can not be modified.
- In order to maintain transparency, native electricity suppliers combining with distribution system operators operate as mine workers, thereby reaching a distributed market system without any central entity.
- For the purchasing and sale of electricity, token-based trading mechanisms are used.
- Distribution system operators is accountable for delay-tolerant data such as monthly expenses ..

This segment provides the specifics of the Blockchain-based smart girdle using Ethereum. The proposed System architecture illustrates the device design, with the implementation of the smart grid over a permission less blockchain of Ethereum. Figure 5 shows the device configuration with a Distribution system operator, native power suppliers as mine workers and full nodes of Ethereum as customers [5][15].

3.1.4 Blockchain Miners and consensus

The various forms of native power providers, such as solar, wind, and biogas, are outlined in Figure 5. Prosumers are local energy suppliers andThey have a two-way flow of power. The miner workers are native power suppliers and DSOs in the proposed system, which creates a transaction block in the proposed system. During the mining method, 15 seconds, thus the introduction of a consensus system by the usage of POW. Mining incentives, assigned to all prosumers, are moved to Ethereum wallets. Likewise, customers often have wallets for their energy consumption. Each transaction is stored in the user and prosumer blocks and Ethereum tokens are used to transport the market payment system[5][12].

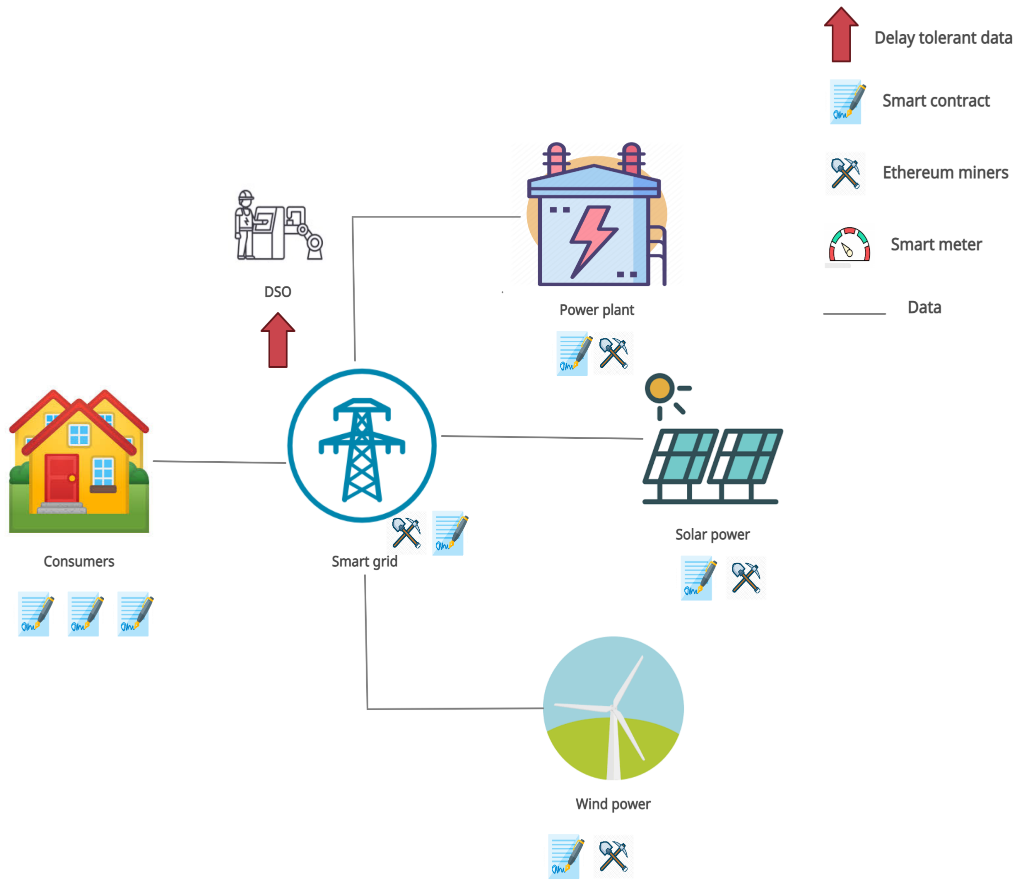

Figure 3.2: Blockchain based smart energy supply using Ethereum

3.1.5 Smart contract

The energy sector is concerned with two smart contracts composed in the Solidity computer language. Contract for smart grid and user contract. The Smart Gird contract involves a mapping under the NewCustomerA situation that maps the addresses of the Meter Reading to its holders. A user contract, which may be either a producer or a customer, is the second contract, relying on the nature of customer. For energy billing, the payment mechanism is used and the getBalance feature is used to display the present amount of coins for the account of the owners.

setCandidate and Powerinfo function is used to store the transaction info in to the blockchain [5][15][17][19][23].

3.2 Workflow of the proposed System

3.2.1 How transaction occurs in the system

We tried to create a Blockchain suited to a smart grid model after learning the different variants of the Blockchain and keeping the interesting points concerning them. In relation to the electrical component of the chain, this first blockchain solution is a mixture of multiple blockchains, which gives us the Smart energy supply. The objective is to create an electricity microgrid network, as in the case of the district of Mymensingh, in order to enable the inhabitants of the same microgrid to exchange their energy output not only with solar energy, but also with all other energy generated (wind, solar, battery, etc.) and thus to gain Energycoin for every kWh of energy produced.In order to achieve an erasure of the energy consumption curve, they facilitate the production of local energy and alleviate the high production of energy. Peer-to-peer sharing versatility is provided by the decentralization component. By combining the initial model of the Smart Grid and the supply of Smart Energy, Fig. 6 summarizes the mechanism by which a transaction between two inhabitants of the same microgrid progresses [1][5].

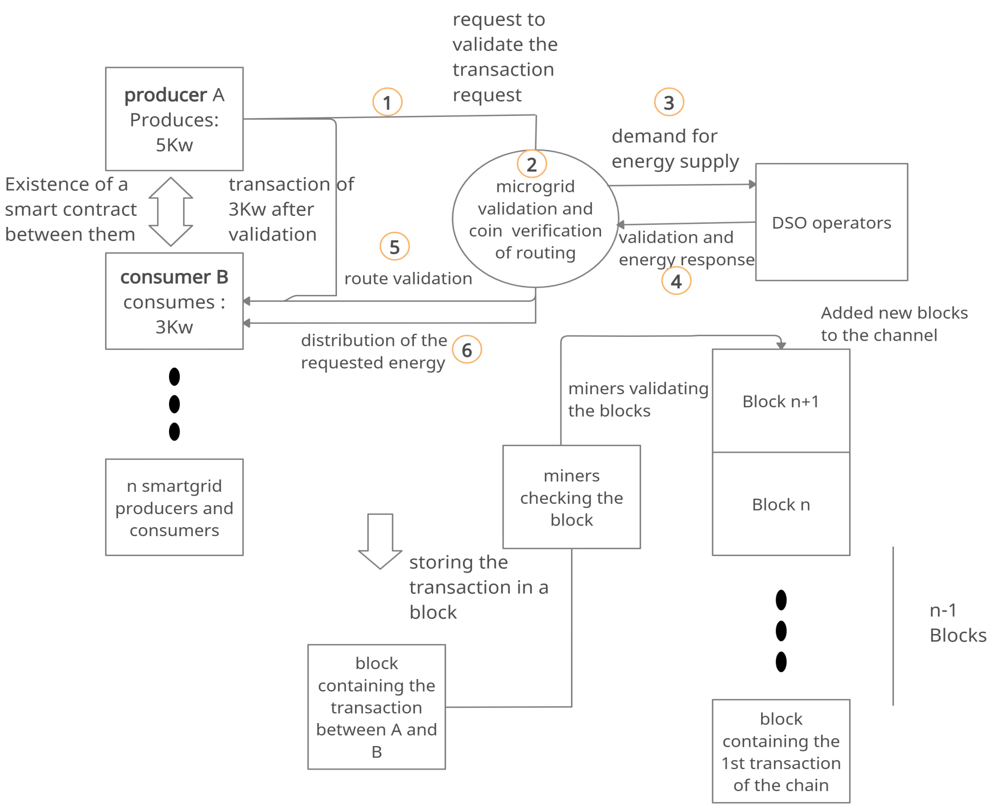

Figure 3.3: How transaction progress in the system

Suppose,

- A produced 5 kW energy

- B wants to consume 3 kW energy

A smart contract is formed between the two entities.

3.2.2 Smart grid level

- According to the rules of the smart contract (A and B), a transaction was intended to be carried out between two persons of the same smart grid; 'A' wants to give 3 kWh to 'B.'
- Based on electrical routing and power line support, the smart grid tests whether it is possible to execute a transaction.
- Once the routing is validated, the smart grid transfers the request to the DSO operators.
- DSO operators furthers investigates the validity of the transaction.
- If the transaction is found valid then it sends a positive response otherwise aborts the request.
- Finally, the Smart grid sends 3kWh energy to 'B'.

3.2.3 Miners level

- In accordance with the rules of the smart contract (A and B), a transaction was intended to be carried out between two persons of the same smart grid, 'A' wishing to give 3 kWh to 'B.'
- Transactions between 'A' and 'B' are deposited in a block with other transactions, and are ready for miners to check. The block is certified if the PoW is checked and then stacked on the oldest chain.

Chapter 4

Algorithm and System implementation

4.1 Algorithm (Pesudo code)

Algorithm 1 System Smart contract

```
Mapping(address => uint256) balances
Init: address of DSO
Constructor(Tokens, new client):
    User= new client
    Balance [User] = InitialSupply
Event Transfer (Sender, Receiver, amount);
Function payment (Requester, Amount):
    If Balance [Requester] >= Amount then
        Balance [Requester] += Amount
        Balance [User] -= Amount
        Return TRUE
    Else
        Return FALSE
    End
Function getBalance(Requester):
Return Balance[Requester]
```

4.2 System implementation

4.2.1 Environment set up

- Ganache: Ganache is a personalized blockchain for Ethereum development, which we will use to install contracts, build our applications, and conduct experiments.
- Metamask: MetaMask is an extension of a browser that lets us access the decentralized system in the browser. It helps us to run Ethereum decentralized apps on our browser without executing a complete Ethereum node.

- Remix : It is a webclient IDE that helps one to compose Solidity Smart Contracts, then apply the smart contract and execute it.

4.2.2 Procedure of storing transaction information the blockchain

We write our code into Remix - Solidity IDE.

```
pragma solidity ^0.4.2;

contract PowerInfo {
    string public _PoweID;
    string public customer_id;
    string public provider_id;
    string public power_amount;
    string public power_per_kw;
    string public payable_amount;
    string public power_plant_type;


    function PowerInfo () public {
        _PoweID = "None";
        customer_id = "None";
        provider_id = "None";
        power_amount = "None";
        power_per_kw = "None";
        payable_amount = "None";
        power_plant_type = "None";
    }

    function setCandidate (string _poweID, string _customerid, string _provider_id, string _power_amount,
    string _power_per_kw, string _payable_amount, string _power_plant_type) public {
        _PoweID = _poweID;
        customer_id = _customerid;
        provider_id = _provider_id;
        power_amount = _power_amount;
        power_per_kw = _power_per_kw;
        payable_amount = _payable_amount;
        power_plant_type = _power_plant_type;
    }
}
```

Figure 4.1: procedure of storing transaction information

4.2.3 Configure

- we set our Environment to Web3 Provider.
- Start run Ganache and copy an address and post he address to Account section.
- Making Gas limit 3000000
- Import the selected Account to Metamask for complete transaction

after complete all the procedure we compile and deploy our contact, New Block created.

- **block: 2tx Index: 0**
- **from:** 0x80B9... 9fCF5
- **to:** PowerInfo.(constructor)
- **value:** 0 wei
- **data:** 0x606...60029

- **logs:** 0
- **hash:** 0x2a2d2abc... 5173be

Status	True transaction Mined and Executed
transaction hash	0x2a2d2abca86b0a8f9c0415afa5b9656a4832e9cb43a650bdba75adc3c95173be
from	0x80B9DD3FF6736CB8BA98c28c26F37316C709fCF5
to	PowerInfo.(constructor)
gas	884279 gas
transaction cost	884279 gas
hash	0x2a2d2abca86b0a8f9c0415afa5b9656a4832e9cb43a650bdba75adc3c95173be
input	0x606...e0029

Table 4.1: Information of powerInfo smart contract

4.2.4 Web implementation of the system's prototype

Since there are various kinds of devices we use in our day to day life such as smartphones, tablets, laptops and desktops. And these devices have different operating systems running inside them. We thought implementing the system in web would be more convenient and hassle free for us. So, we implemented our blockchain based smart renewable energy management system online. Users can easily access our system with theirbrowser. The system is still in perpetual beta stage, meaning few features are continually added to the system.

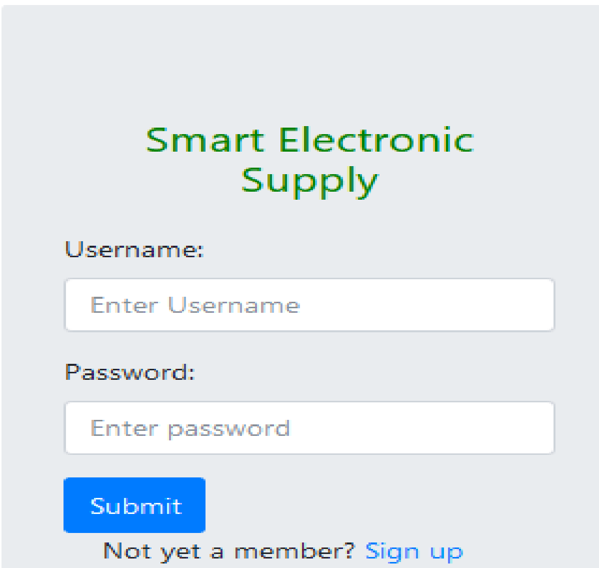

Figure 4.2: Log in screen

Users can log in to the system with their user name and password.

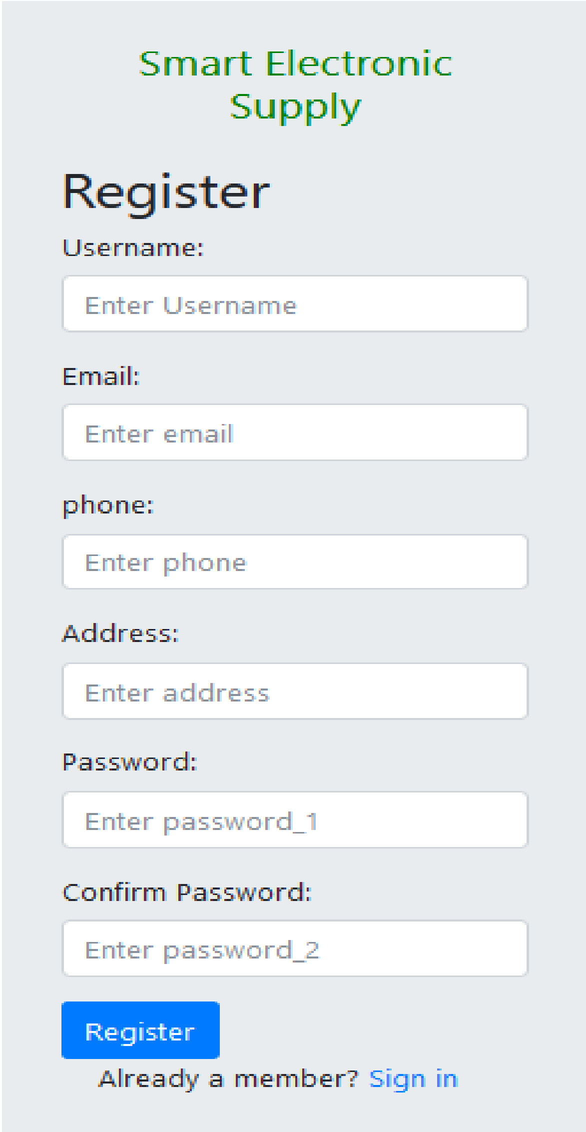

Figure 4.3: Sign up screen

They can also sign up in to the system by providing their username, email address, address, phone number and password. User can also search for their desired type of power by typing in the search option on the top right. They can also search for their desired amount of energy by using the search bar. They can also search for the amount of coin per kW they are looking to spend on.

Upon logging into the system, user can see their energy balance on the up left of the screen. Shown on figure 4.4 below, user can create post for selling their desired type of power like solar energy , wind energy etc. They can also choose the amount of energy(kw) they want to sell. Furthermore, they choose amount of price they want to charge per kw. They would also be given a unique plant id to identify their energy resource.

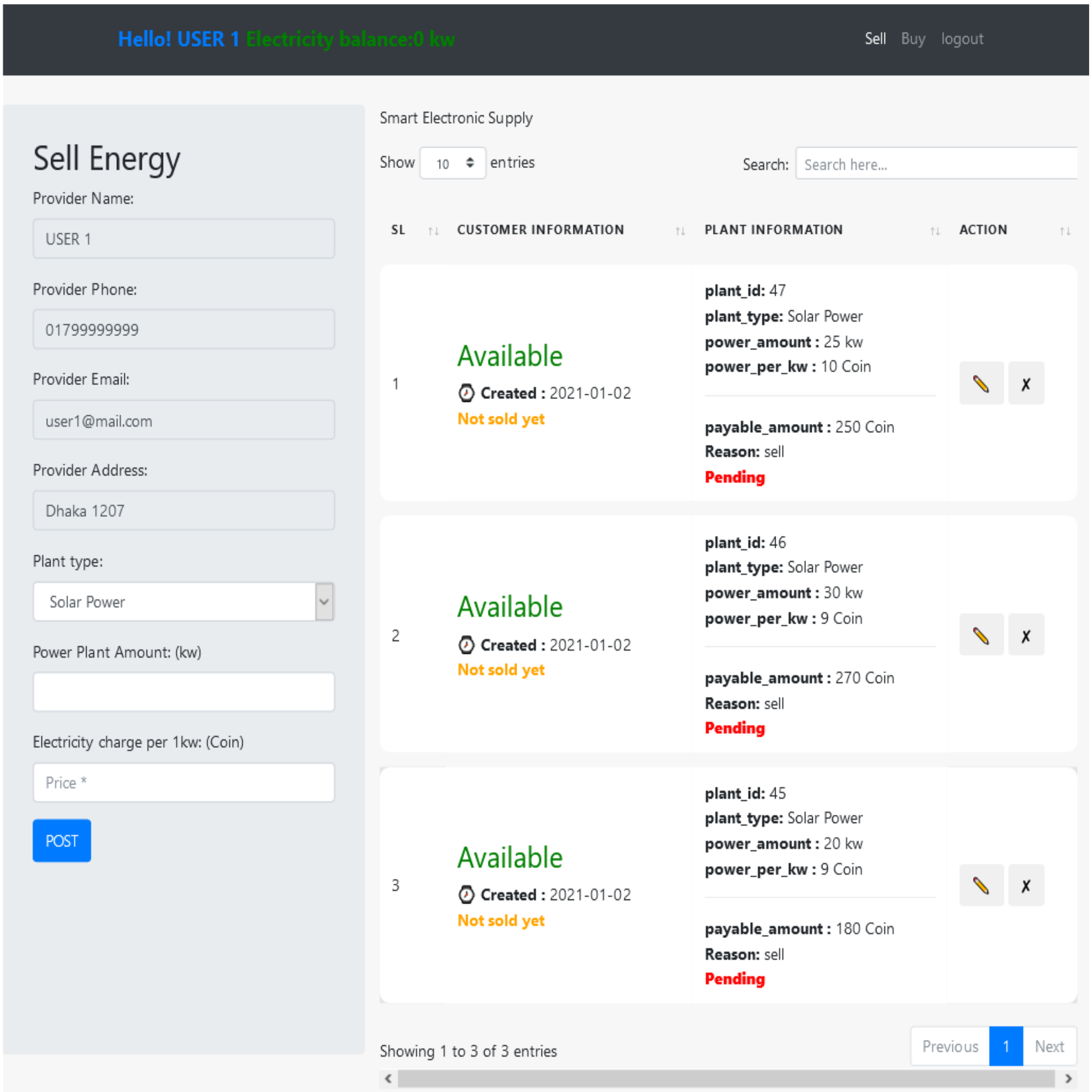

Figure 4.4: Sell post by USER 1(USER 1 As Energy Provider)

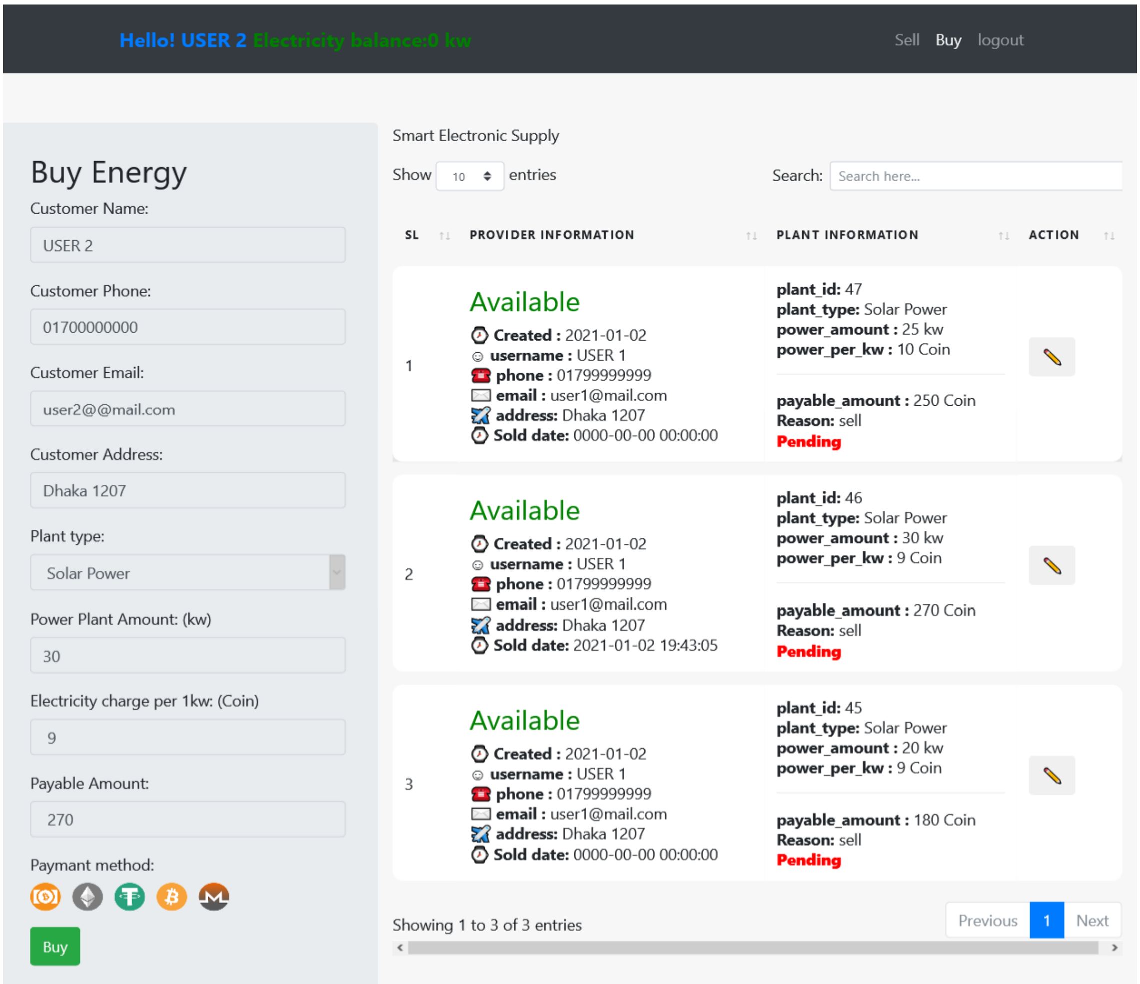

Figure 4.5: Buying Energy from plant id=16 by user 2

In the BUY section, user will be able to see the available and sold ads. Within those adds they could see the creation date of the ad, username of the ad poster, cell phone number of the provider, email address of the provider, location etc. Buyer can also see the type of power provider want to sell, power amount and the amount of coin the provider want to charge per kW.

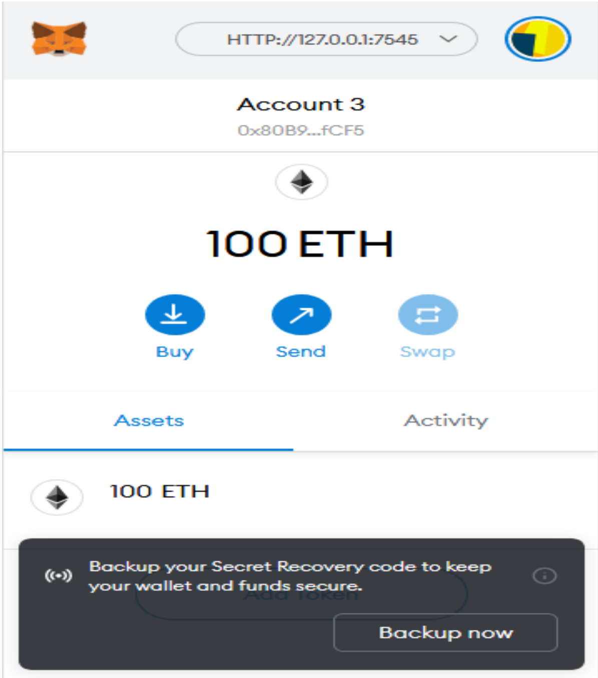

Figure 4.6: Balance before completing a transaction (Metamask)

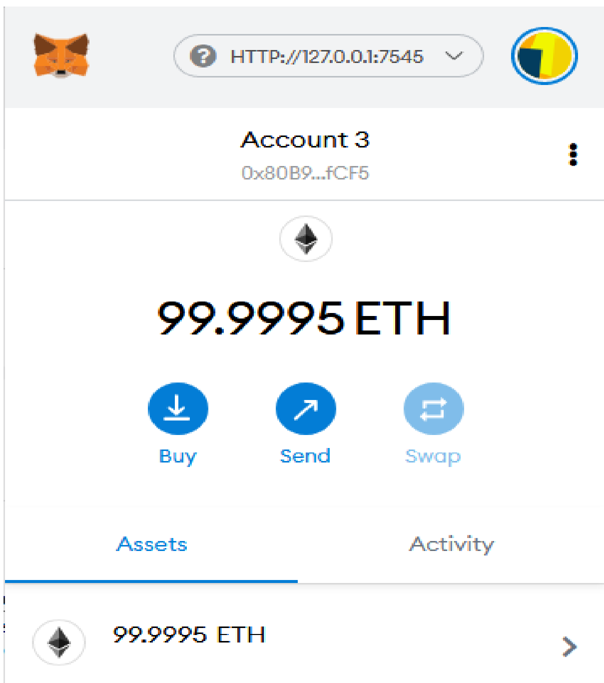

Figure 4.7: Balance after completing a transaction (Metamask)

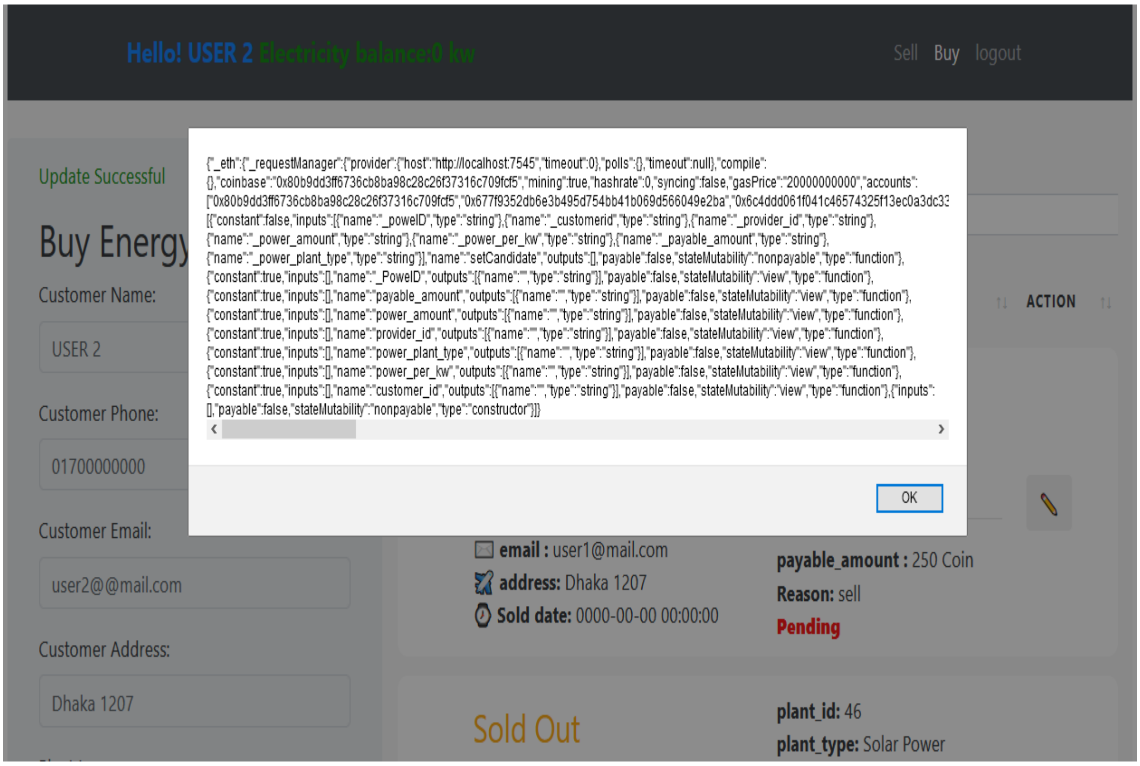

Figure 4.8: After energy purchase transaction report shown as Json.

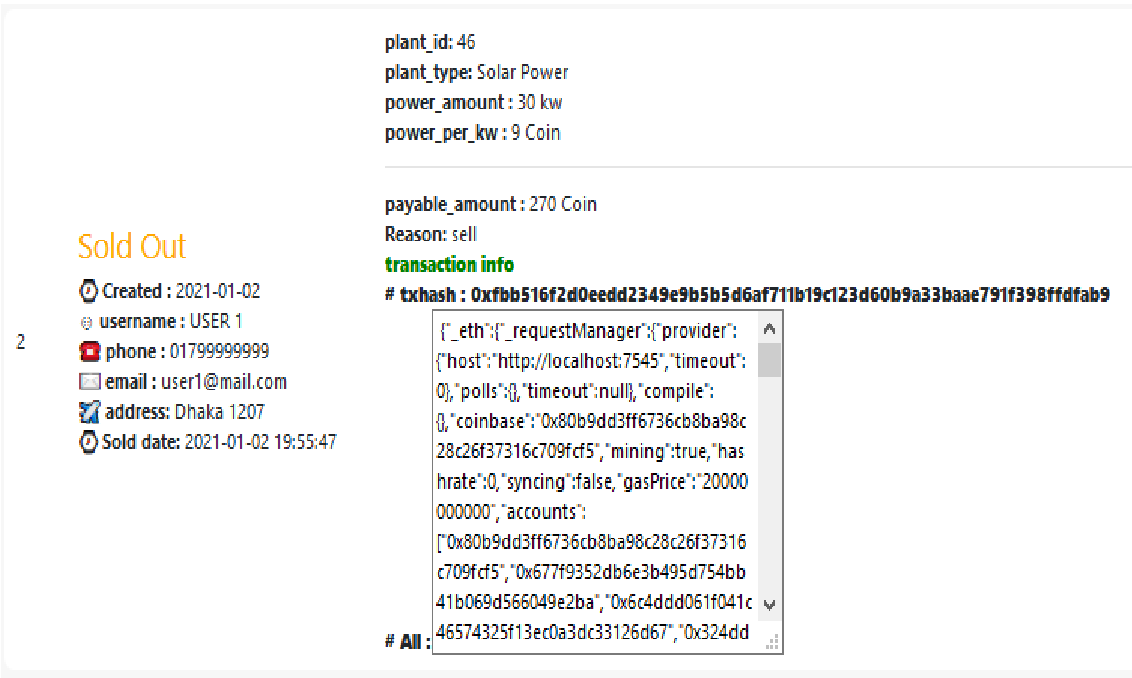

Figure 4.9: After energy transaction view transaction info as public data.

After purchasing the desired amount and type of energy from the provider. The transaction will be complete and the transaction information report will be shown as Jason. By clicking on the transaction info user can also see the transaction hash, as shown on figure 4.8 and 4.9 above.And the ad will be marked as sold out with the sold date attached to it. Meaning it is unavailable for trade. As shown on figure 4.10, after transaction user's energy balance will increased accordingly.Users can also buy coin from the website with their desired payment option shown in figure 4.11.

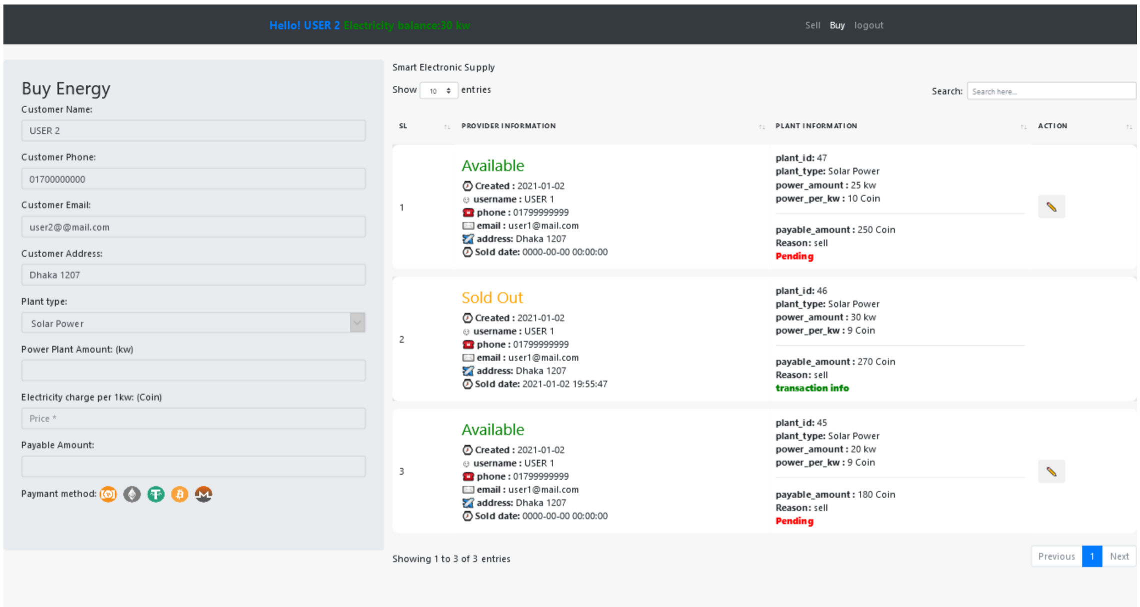

Figure 4.10: Energy balance increased after purchase(plant id(46) purchased by USER 2)

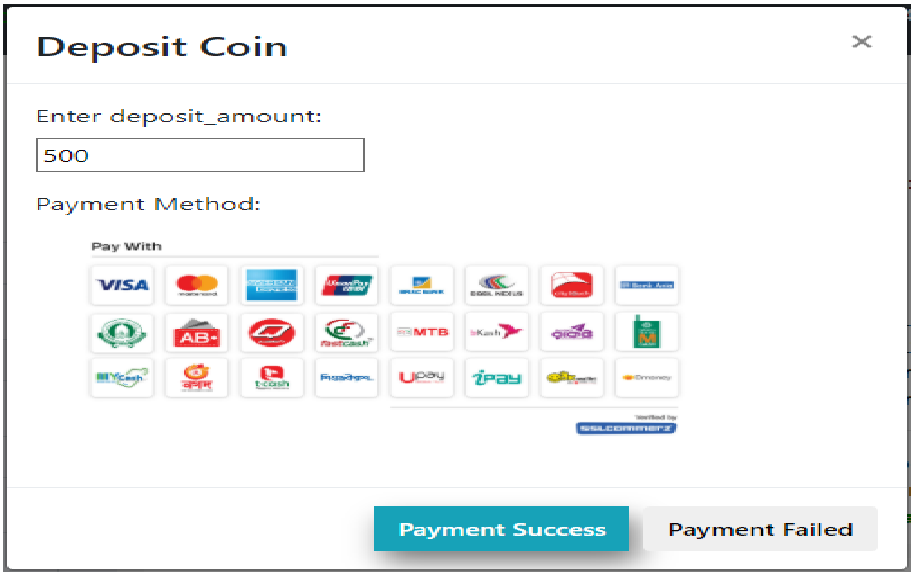

Figure 4.11: Coin deposit by USER 1

Chapter 5

Result and analysis

Task	Gas usage	cost(dollar)
Smart contract of grid	674,511	0.1429
Execution tariff of smart grid contract	471,501	0.1001
User contract	322,239	0.0683
Transaction execution cost	23,550	0.0049
getBalance function cost	36,012	0.0074

Table 5.1: Execution cost of smart contract

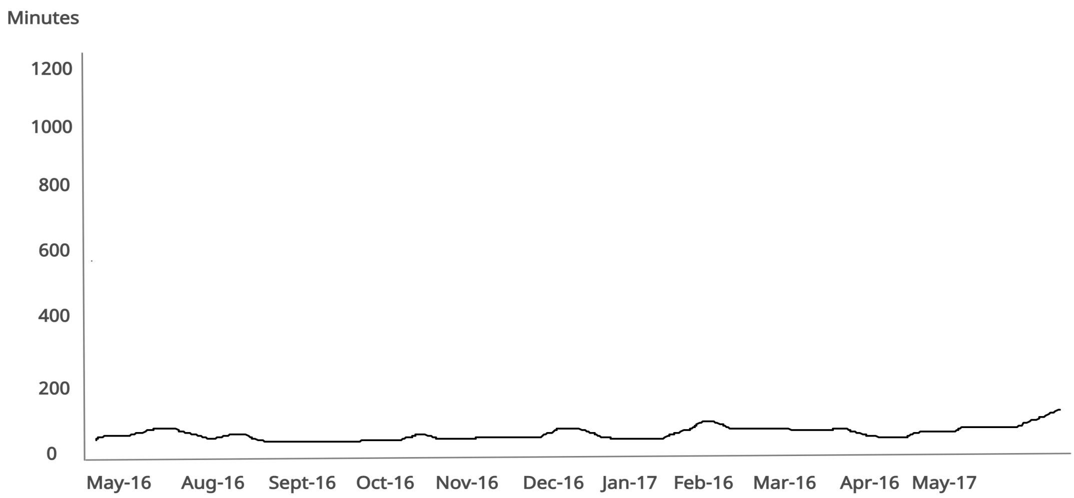

Figure 5.1: Bitcoin's daily average conformation time of transaction over a year

there is a cumulative gas cap of 3,000,000 for the smart contracts deployed using the local Ethereum blockchain . As displayed in Table no. 2, the transaction price

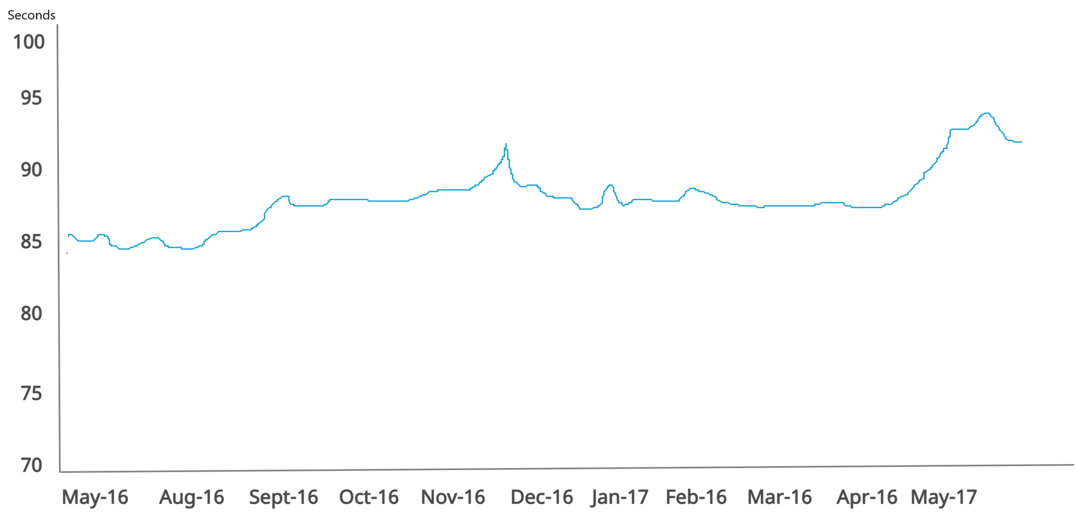

Figure 5.2: Ethereum system's daily average transaction time over a year

of the smart grid contract was 674,511 gas and the execution tariff was $0.1429 We have a maximum transaction is 6 TP/S. And if you alter the expenditure every 15 minutes, it is possible to represent 5,000 households in an ideal situation that is useful for nanogrids.

5.0.1 Discussion

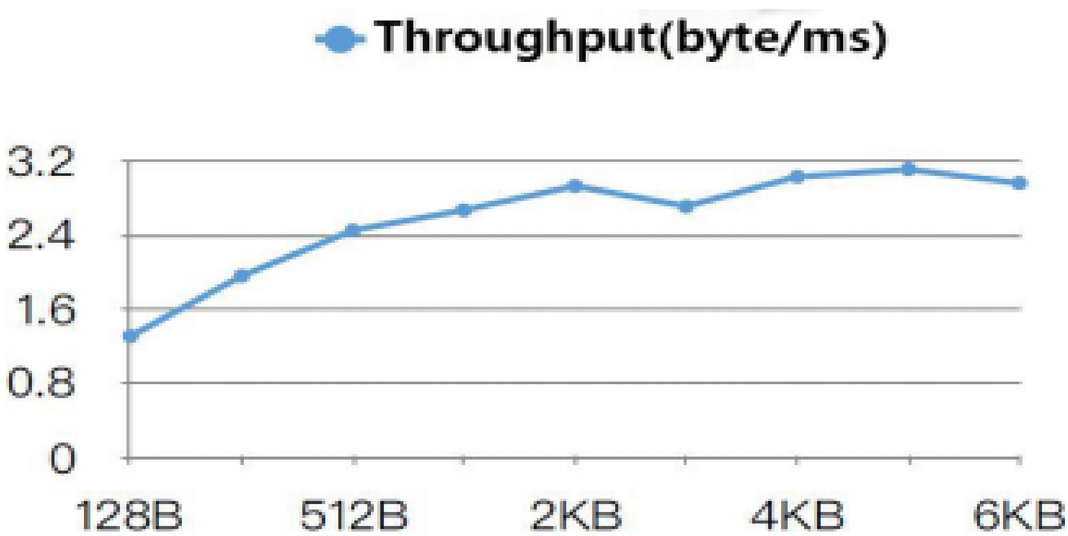

Figure 5.3: The blockchain's efficiency and information density per operation

While blockchain can be an evolving Innovation, It is willing to carry credibility to the domain of business and human society. Efficient, blockchain-based cases of real-world business usage are still uncommon. One major obstacle and difficulty for the implementation of blockchain in various industries is that up to now Blockchain technology does not handle information in an efficient manner. That's why in actual business systems and apps, a full-blockchain framework could fail. The integration of two various methods of taking input and proving output in different industries is a realistic approach for applying blockchain technology to different industries.[25]

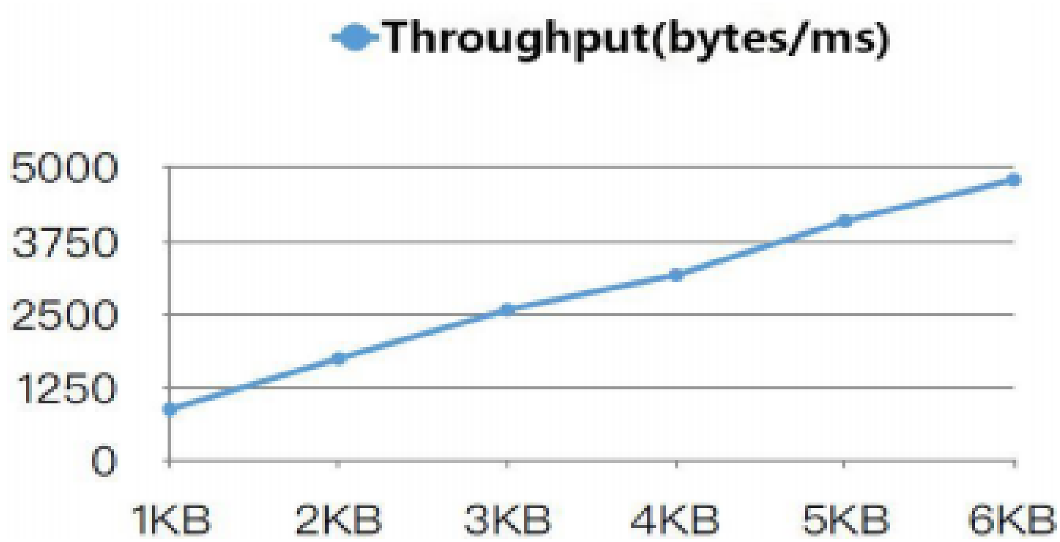

Figure 5.4: The relational Databases's efficiency and information density per operation

The whole system must then be broken into modules which are information oriented. And modules which are non-information-oriented. For the high requirements of information reading and writing, information-oriented tasks can be based on native databases. And a blockchain can be built on non-data-intensive modules. Another realistic approach is to restructure the design of their trading model. The system can be divided into integrity and non-integrity-related sections. The faith and protection aspect of the data volume should be simplified, using cryptographic hash output, for example, to satisfy the information input and output efficiency of the blockchain. So, to secure their business, they can enable usage blockchain technologies.[25]

And the non-integrity and safety component can reserve greater amount of comprehensive data and be based on native databases. A fair compromise can be found with the research results data and company criteria to achieve the best balance between success and safety[25].

Types	Bitcoin	Our system(using Ethereum)	Our system(HyperLedg Fabric)
Purpose of system	Cryptocurrency	Running smart contracts	Creating blockchain for industrial purposes
Type of data can be saved	Transactions of cryptocurrency	Digital assets, smart contracts, cryptocurrency	Chain code, smart contracts
Programming language	script	solidity	Chain code
Type of ecosystem	open	open	Not open
Type of authority	decentralized	decentralized	centralized
Time complexity of block generation	10 minutes	12 seconds	configurable
Size of transaction	250 bytes on an average	89KB(maximum)	configurable
Cryptocurrency type	bitcoin	ether	n/a
No. of transactions confirmed per second(throughput)	4.6	15	configurable
Mining mechanism	Proof of work	Proof of work using Ethash algorithm	N/A

Table 5.2: performance analysis of proposed system.

Chapter 6

Conclusion

In our research work, we have proposed virtual blockchain-oriented technology, Smart grid framework that utilizes smart business contracts transaction and functions connected to it. The architecture suggested was applied by using Ethereum. With the help of ethereum local blockchain network and development tools we incorporated a web implementation of our proposed system. Where user trade in renewable energy in case of energy scarcity. The paper draws a performance comparison between ethereum and existing bitcoin technology. And shows that it has the capability to reduce government intermediary and encourage local producers to decrease the gap in our energy production. It emphasizes on a transparent energy trading and provides satisfactory security in trading with the help of blockchain network. It implements the advantages of blockchain and shows that this new technology can be used in many aspects of our day to day life. Furthermore, it encourages us to use green energy and depend less on nonrenewable energies.

6.1 Drawbacks and future works

We could implement our proposed system directly into a blockchain network. Due to various inconveniences we had to implement our system locally with help of ethereum development tools. Due to lack of financial support we had to comprise various things. During our thesis project, the Covid-19 virus spread through all parts of the planet. So, all worldly things, therefore, come to an end. There was a lockdown scenario all over the place in which we did our work through an online operation. During this case, we cannot just literally meet with the supervisor. Even though our supervisor was unable to make any physical contact with us. Also, our system could provide significant better results if the same algorithms were implemented in the Hyper Ledger blockchain. Even though, there are few factors associated with it such as the system would lose its decentralization manner and openness. But the performance and the scalability would be much better. With the deployment of Hyperledger Fabric v.12, we will have a major upgrade from 6 Threshold per scond to 96 Threshold per second. Even if the average tps is 90, in 15 minutes, more than 81000 households can be served. So, in the future we would like to implement our system in the Hyper Ledger v.12. And we would also like to explore various security aspects that come with it.

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