
An Electronic Double Auction of Prepaid Electricity Trading Using Blockchain Technology

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Abstract

Thailand's current energy trading system is an Enhanced Single Buyer (ESB), a market monopoly by a single buyer. It will produce and distribute electricity to service providers in each area, enabling them to distribute services to consumers. In terms of the consumer aspect, it is necessary to purchase electricity from only one seller, and it is not possible to choose the manufacturer independently. Since the price mechanism is not competitive, the market price is mainly determined by a single buyer. Meanwhile, alternative energy power generation technology has progressed. Anyone can become a power producer using wind power or solar energy. People can easily produce electricity to use in their households. Besides, residual energy from use will be sold only to the ESB. However, there is a selling restriction because there is only one buyer. Importantly, Blockchain technology can be applied to enable independent electricity trading. In other words, called peer-to-peer (P2P) trading, the Thai government has policies to promote P2P trading. However, there are not many systems supporting P2P energy trading since P2P trading is still in the beginning stages of the Pilot Project. In this study,

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the researchers have presented a P2P Power Trading Model using Blockchain technology. This research presents a system with efficiency and simplicity. Also, there are other technology highlights such as IoT, Lora, and Electronic Double Auction. The researcher has designed, implemented, and tested it for actual electrical power trading. It can prove to be traded according to the designed test cases. Importantly, we are truly confident that this research will benefit those interested in developing real-world applications. This research can also be used as an alternative to the traditional power purchase and sale system.

Keywords: Electricity trading, energy trading, electronic double auction, micro grid, IoT, Lora Wan, prepaid, Ethereum blockchain.

1 Introduction

The electricity demand is continuously more significant than previously, and the demand aims to increase both across the globe and in Thailand. Electric power is significant to today's sustenance and in the future with the electric utility infrastructure. We have seen the rapid development of electric vehicles gain more and more widespread popularity in the past. It is the catalyst for the demand for electric power in the same direction [1]. Energy sources used to generate electricity today include nuclear fuel, coal fuel, natural gas, and others. The mentioned energy is causing air pollution, so the tendency to use energy is steadily increasing while energy sources are limited. For this reason, it may cause an electricity shortage in the future. The government is therefore interested in promoting the use of energy from alternative energy sources. One of them is the production of electricity from solar energy, which is clean energy without pollution. Solar cells are cheaper and can be easily purchased. Minor users can easily install solar cells by themselves, and the system is flexible to use. The popularity of solar cells has been steadily increasing in Thailand. The electricity generated from solar cell production is used in addition to being used in their own homes. It can also be sold to the electricity authority by installing inverters and smart meters. In addition to the extensive buyer's grid, the energy generated is to be used inside households. If there is a surplus of energy, it will be sent to the grid, which is the sale of electricity. However, Thailand has a power distribution system in Thailand, and it is a monopoly owned by a single buyer. Enhance Single Buyer Thus, the Thai government will allow free electricity trading shortly [2]. Microgrid electrical trading is another essential solution.

If the house is located in an area without access to electricity, such as villages in remote areas or islands, generating electricity from solar cells is a good choice. In this case, a battery is needed to store electrical energy when there is no sunlight. In Thailand, solar cells were installed to generate electricity for use in households only. Also, there was a systematic power trading system. The closed electricity trading system was a considerable challenge to revolutionizing the electric business in the areas that have limited access to electricity.

Blockchain technology is an essential tool that can be applied to electricity trading one-to-one without going through an intermediary. Buyers can choose their sellers, where the information is accurate with data transparency. Also, there is Crypto Currency, an essential tool for transactions that can be used for trading. Using Cryptocurrency is a revolutionary form of energy trading that has been used for a long time. Electricity trading with blockchain technology is likely to be more popular, especially in the United States. [3] The Brooklyn Micro Grid is currently managed by LO3 Energy, a company that provides microgrid networks. In addition, [4] The Power Ledger company in Australia began developing the system on Ethereum to create their platform and currency. Then, they expanded to other countries, such as New Zealand, Japan, and Thailand. For Thailand, the government has also encouraged the development of a P2P energy trading platform under the National Energy Trading Platform project to support further P2P energy trading.

2 Theories and Relevant Research Reviews

Electric Power Trading with Blockchain Technology

According to research related to the P2P power trading system, the relevant searches were IoT, Blockchain, P2P, Energy Trading, and Microgrid. We can classify research into 3 groups: (1) A group that conducts research using a computer simulation. (2) A group that conducts implementation research; (3) a group that is being tested in the business world. The mentioned group is illustrated in Table 1.

Based on the classification of the electric energy trading model with blockchain technology at the research level and the production level, the enterprise group is not impacted by foreseeing business gaps that may affect it in the near future. In order to gain a more practical understanding of the power purchase process, the researcher focuses on details of the structure, power

Table 1 Peer-to-peer energy trading comparison and at related events

Application Level	Developer	Platform	Matching	Propose	Payment	Feature	
Simulation	Pradip Kumar [5]	Ethereum		S. City	n/a	IoT	
Research	Naram Mhaisen [6]	Ethereum			n/a		
	Mohammad [7]		Auction	Parking lot	n/a	Meter	
	Long, Chao [8]	Ethereum	D.Auction	S. Grid		Charging	
	Magda Foti [9]	Ethereum	D.Auction	P. Grid			
	Su Nguyen [10]			L. Scale		Battery	
	Ying Wang [11]	Ethereum	Bidding	Microgrid		Dimension	
	Chenghua [12]	Ethereum	Bidding	Microgrid		Manage	
	Chaudhary [13]	Ethereum	Bidding	S. Grid		IoT	
	Zhiyi Li [14]	Ethereum		Microgrid		Manage	
	FSanchez-Sutil [15]			Control	n/a	Lora	
	Hamada [16]			S. Grid		Solving	
	Sana Noor [17]	Ethereum		Microgrid		Manage	
	Solar Coin [18]			Consortium		Meter	
	Realistic/ Implementation	Tonghe [19]			Microgrid		
Research		Kambule [20]		Exploring	prepaid	Trend	
		Arne [21]	Ethereum		Microgrid		
YanniJiang [22]		Ethereum	Game TR.	Microgrid			
Yikui Liu [23]			Auction	Microgrid			
Lüth [24]				Smart grid		Balancing	
Mateo[25]				L. Scale	prepaid	Payment	
Xiaonan Wang [26]		Ethereum		Microgrid		Manage.	
Project/ Enterprise		Power Ledger [27]	Ethereum	D. Token	L. Scale		
		Divvi [28]	Ethereum		L. Scale		With Map
	Electrify.Asia [28]	Ethereum		L. Scale			
	Electron [28]	Ethereum		L. Scale			

supply production, trading, and payment. The study reveals that there is not much technical information, especially about the payment system, which is an important mechanism that is indispensable. However, the payment mechanism is often not explained. Thus, the research focuses on the groups with implementation research, with a complete presentation of the power trading system in every step.

2.1 The Model of Auction Mechanism

Auctions are competitions in bidding to acquire or sell a product. The bidding winner has the right to buy or sell items that he/she has auctioned at that time. The purpose of all three auctions can be classified as the study of the current auction format, including forward auction, reverse auction, and the last one

Table 2 Comparison of each auction format

Auction Format	Advantage	Limitation	Cheating
Forward Auction	The offeror has the price advantage. able to set a self-acceptable minimum selling price.	Buyers are at a disadvantage as prices are set by a single seller.	Fraudulent joint ventures between buyers can occur.
Reverse Auction	The offeror has the price advantage. able to set a self-acceptable minimum selling price.	The seller is at a disadvantage because the price is set by a single buyer.	Fraudulent mergers between sellers can occur.
Doubled Auction	Bidding may begin with an offer or an invitation. Therefore, it is fair to both parties.	The system is quite complex. Development is quite difficult.	Fraudulent co-operation in auctions is difficult.

that includes both bid and ask, called Doubled Auction. A comparison of the advantages and limitations of the three auction formats is shown in Table 2.

- **Forward Auction:**

Selling an Auction, it is an auction that begins according to those who want to sell the product. The seller stipulates that the buyer wants to bid competitively. The buyer with the highest bid wins the auction and is entitled to purchase the item.

- **Reverse Auction:**

Purchase auctions, it is an auction that begins according to the wishes of those who wish to purchase the item. The buyer determines the purchase demand for the seller to offer a competitive price. The seller who offers the lowest price will win the auction. Besides, the buyer must purchase the item from the seller who won the auction at that time.

- **Doubled Auction:**

A dual auction is a combination of forward auction and reverse auction systems. Therefore, it can be both a bid and an offer department, such as at a stock market auction.

2.2 Payment System for Goods and Services

Nowadays, there are two types of payment for goods and services. First, pre-billing for goods or services, also known as prepaid or billing systems, After the product has been delivered or completed, the service is known as “postpaid.” Examples of products billed as prepaid and postpaid include phone signal usage fees, service fees for using internet signals, and others.

Table 3 The comparison of prepaid and postpaid payment

Comparison Topic	Prepaid	Post Paid
1. Operational processes	Simple and not complicated	Complicated
2. Cost	Less billing costs due to short and uncomplicated processes with no debt collection.	It costs a lot to operate due to complex procedures since there is a follow-up on debt collection and service is temporarily suspended. The return of the service will be made after the outstanding payment has been made.
3. Popularity	More popular	Less popular
4. Service areas coverage in Thailand	Covers both urban areas and remote areas.	Covers only urban areas

Currently, most charges for buying and selling electricity are postpaid, while some offer prepaid billing, including vending machines for recharging cell phones, among others. A review and identification of persistent and emerging prepaid electricity meter trends The prepaid electricity meter market is expanding globally [20]. In Thailand, with more than 80% of all users of the prepaid telephone market [29]. This experiment chose the prepaid billing system because it is more streamlined and flexible than postpaid billing. The advantages and limitations of both types of payment are stated in Table 3.

3 Structure and Working Mechanism of the System

This section provides an overview of the Electronic Prepaid Dual Power Trading Auction System using Blockchain Technology. The structure of the entire system consists of four layers, as shown in Figure 1. Meanwhile, an overview of how the entire system is interconnected is shown in Figure 2.

3.1 Infrastructure Layer

The infrastructure layer is the hardware used in the production of fire, storage, and electricity, such as a power generator to replace the solar cell used to generate electricity. Besides, an electric charge control circuit to store electrical energy into a 5KWH battery, representing the use of electricity, which consists of 4 houses, each with a Smart Meter installed to measure the electrical energy. The electricity production side and the electricity consumption side have to work through devices to bring electricity to work, and

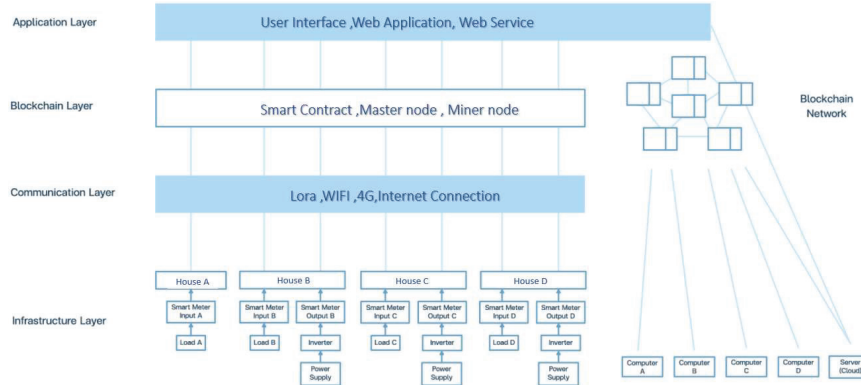


Figure 1 The structure of the four-layer system.

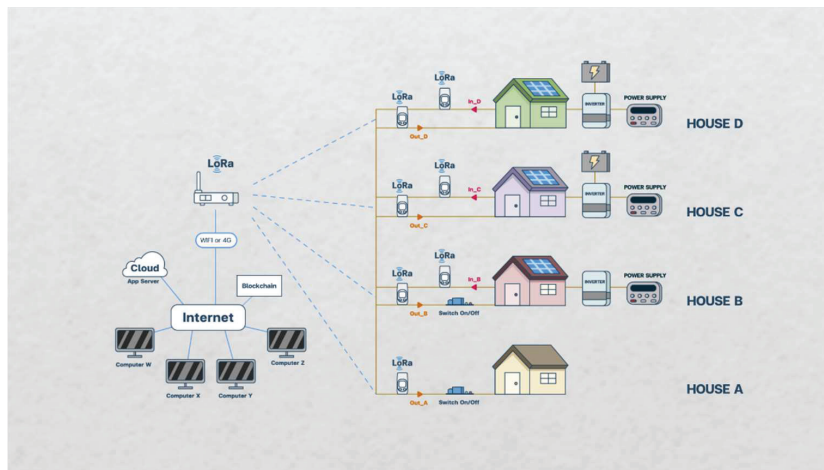


Figure 2 Overview of the interconnection system.

the inverter will convert power to alternating current again. The electrical equipment used in this test was a 220-volt 40-watt lamp and a 220-volt 45-watt fan, and it also had a power control circuit and cut off the power to the house. It will be controlled by a Smart Contract.

A mathematical model is used to describe microgrid power generation and distribution systems. The sum of all-electric power generation sources is equal to the sum of all-electric energy consumption [30], which can be explained by Equation (1) as follows:

$$E_{g(i)} + \mathbf{E}_{b(i)} = E_{c(i)} + \mathbf{E}_{s(i)} \quad (1)$$

By

$E_{g(i)}$ is the power generation of the microgrid system, the source of $i = 1, \dots, M$

$E_{b(i)}$ is the electricity consumption of the microgrid system, the source of $i = 1, \dots, M$

$E_{c(i)}$ is to sell electricity from the microgrid system, the source of $i = 1, \dots, M$

$E_{s(i)}$ is to sell electricity from the microgrid system, the source of $i = 1, \dots, M$

M is the electricity source of microgrid system

3.2 Communication Layer

The communication layer is the part used to receive and transmit data. The system starts by reading the electricity used from the Smart Meter and converting the data into the form of Lora radio signals for transmitting data between IoT. This Lora signal highlights that it is a technology that can communicate wirelessly over a long distance and consume very little power [31]. When connected to the Internet with a Wi-Fi signal, when the Lora Gateway receives the Lora signal, it converts the signal to MQTT format due to its fast transmission and small size [32]. It will be forwarded to the Cloud, which will install the MQTT Broker. It will be sent to the Blockchain Network once it receives the data.

3.3 Blockchain Layer

The Blockchain Layer consists of Cloud-Based Nodes and other non-cloud nodes, collectively referred to as the Blockchain Network. In this experiment, Ethereum is a platform where Ethereum is a popular tool to develop as a platform for trading energy with the world's blockchain [33] It is being developed as a decentralized application (DAP). Furthermore, this application was created in Solidity language to create the terms of the program that we wanted to function as we specified, including the double auction, payment, and payout sections. For power or cut-off power, the developed program is called a "Smart Contract," an essential mechanism for managing all the information in the system.

3.4 Application Layer

The Blockchain Application Layer is used as a way for users to communicate with the Blockchain Layer. It can be divided into 3 parts: (1) Purchase or

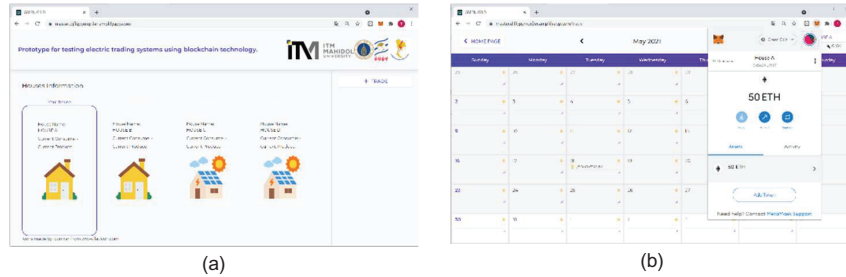


Figure 3 (a) Application main screen and (b) Auction home screen.

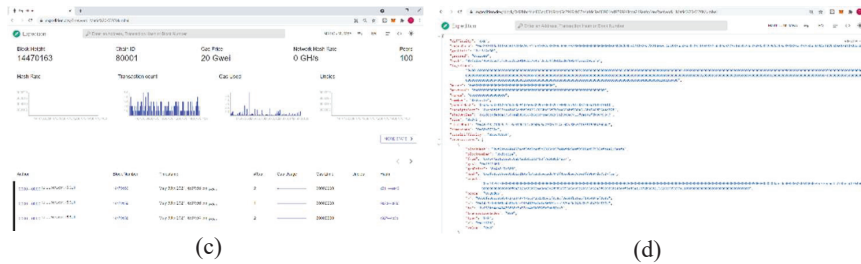


Figure 4 (c) Transaction history and (d) Details of the information in the block.

order an offer. Including the ability to buy, offer, sell, or order via a web application. Users can access transactions using standard web browsers such as Google Chrome, Opera, or Firefox. Payments are made through Meta Mask, an open-source program that acts as a wallet for cryptocurrencies. (3) a piece of transaction history. Users can use the program’s Web browser to open the previous item. including a search for transaction history. The trading application screen is shown in Figure 3, and the transactions recorded on the blockchain screen are shown in Figure 4, and the algorithm for bidding is shown in Figure 5, and the algorithm for pairing is shown in Figure 6.

4 Scenario Use for Assessment and Test Results

4.1 Conditions of Trading Test

Tests for this research project were designed to be consistent with various situations in microgrid systems. Thus, five types of test conditions are defined and shown in Table 4.

Algorithm 1: The function for get best order

```

1  function getBestOrder(GreenGridCommon.Side side) public view
2  returns(GreenGridCommon.Order memory) {
3      if(side == GreenGridCommon.Side.BUY) {
4          if(bestBids.length > 0 && mapBidsByPrice[bestBids[0]].length > 0) {
5              return mapBidsByPrice[bestBids[0]][0];
6          }
7      } else {
8          if(bestOffers.length > 0 && mapOffersByPrice[bestOffers[0]].length > 0) {
9              return mapOffersByPrice[bestOffers[0]][0];
10         }
11     }
12     return createBlankOrder();
13 }

```

Figure 5 The function for get best order.

4.2 Trading Process

The trading process can be started as a buyer offeror or seller offeror. In order to understand the steps in detail, they are described in Figure 5 and explained by example.

Example 1: In the case of being a buyer, the steps are as follows:

- Inform the amount of electricity and unit price that a buyer wants to purchase and transfer money to the system.
- Other buyers enter the competition by doing the same as the first.
- The system will select the person who bid the highest price and show it to all buyers in the system.
- The seller makes a sales transaction by receiving money from the system into the wallet immediately.
- The system will turn on the switch at the buyer's house and cut off the power when the amount is reached.

Example 2: In case of being a seller, the steps are clarified as follows:

- Inform the amount of electricity and the price per unit that the seller wants to sell.
- Other sellers enter the competition by doing the same as the first.

Algorithm 2: The function for create Matched by order

```

1  function createMatchedByOrder(GreenGridCommon.Order memory matchingOrder,
2                                GreenGridCommon.Order memory matchedOrder,
3                                uint matchingPrice) private returns (GreenGridCommon.Matched
4  memory returnMatched) {
5      uint matchedLot = matchingOrder.lotSize <= matchedOrder.lotSize ?
6  matchingOrder.lotSize : matchedOrder.lotSize;
7      GreenGridCommon.Matched memory newMatch = GreenGridCommon.Matched({
8          who : matchingOrder.who,
9          whom : matchedOrder.who,
10         side : matchingOrder.side,
11         limitPrice : matchingOrder.limitPrice,
12         matchedPrice : matchingPrice,
13         lotSize : matchedLot
14     });
15     GreenGridCommon.Matched memory counterMatch =
16     GreenGridCommon.Matched({
17         who : matchedOrder.who,
18         whom : matchingOrder.who,
19         side : matchedOrder.side,
20         limitPrice : matchedOrder.limitPrice,
21         matchedPrice : matchingPrice,
22         lotSize : matchedLot
23     });
24     matched[matchingOrder.who].push(newMatch);
25     matched[matchedOrder.who].push(counterMatch);
26     return newMatch;
27 }

```

Figure 6 The function for create matched by order.

- The system will select those who offer for sale. The lowest price is shown to all sellers in the system.
- The buyer makes a transaction to transfer money to the system. Then, the system will transfer to the seller immediately.
- The system will turn on the switch at the buyer’s house and cut off the power when the amount is reached.

Table 4 Five conditions used in the test

Test Cases	Tenderer-sell		Tenderer-buy	
1. Competitive bidding with different prices.	A	B	C	D
2. Competitive bidding for the same price.	A	B	C	D
3. The competition is offered at different prices.	A	B	C	D
4. The competition is offered at the same price.	A	B	C	D
5. tender offer in case of insufficient power.	A	B	C	D

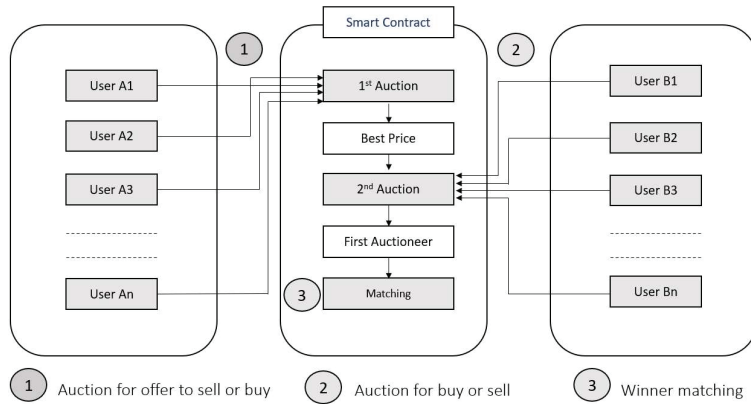


Figure 7 Double auction flow.

Electricity Charge

When there is a winning bidder, the system will turn on the power switch of the winner’s house that won the auction from the electricity bill that can be used with the calculation principle [34] by calculating the electricity cost according to Equation (2), where:

$$Total\ cost = \left(\sum_{i=1}^n Power.Hour \right) price \quad (2)$$

By

- Total cost *is total electricity cost in units of Ether (ETH)*
- Power *is the electrical power of an electrical appliance in units of Watt (W)*
- Hour *is the number of hours the appliance is used in units of Hour (H)*
- Price *is the selling price of electricity per unit in units of WH/ETH*
- n *is the number of electrical appliances that are in use during that period*

Table 5 Results of E-double auction testing for the competition offerings

Test-Case	Buyer				Seller				Results		
	House A		House B		House C		House D		Winner	Paid (ETH)	Used (min)
	WH	ETH	WH	ETH	WH	ETH	WH	ETH			
Buy-different prices (1)	10.0	3.0	20.0	4.0			20.0	4.0	B-D	80.0	26.67
Buy-different prices (2)	20.0	5.0	10.0	3.0	20.0	5.0			A-C	100.0	26.67
Buy-same prices	20.0	2.0	20.0	2.0	20.0	2.0			B-C	40.0	26.67
Sell-different prices (1)	10.0	2.0			30.0	3.0	10.0	2.0	D-A	20.0	13.33
Sell-different prices (2)			25.0	4.0	25.0	4.0	30.0	5.0	C-B	100.0	33.33
Sell-same prices	25.0	4.0			25.0	4.0	25.0	4.0	C-A	100.0	13.33
Buy-surfacial power	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Note: In case that offers to buy or offer for sale at the same price, the first bidder will win the auction.

4.3 Actual Trading Test Results

The test results for electricity purchase and sale by using electricity from all 5 cases used in the Prepaid Double Auction electricity trading case test can be summarized in Table 5. The test results are as follows:

- Case 1: The competition offers to buy at different prices. House A can be paired with House D for 10 WH at 3 ETH/WH, pay 30 ETH, and can use electricity for 26.67 minutes. The total amount of electricity will be cut off.
- Case 2: The competition offers to buy at the same price. House A can be paired with House C for 20 WH at the price of 5 ETH/WH, paid 100 ETH, and can use electricity for 26.67 minutes and when used. The total amount of electricity will be cut off.
- Case 3: The competition offers a different price. Baan B can be paired with House C for 20 WH at the price of 2 ETH/WH, pay 40 ETH, and can use electricity for 26.67 minutes and when used. The total amount of electricity will be cut off.
- Case 4: A competition offering the same price, Baan C can be matched with House A for 10 WH at the price of 20 ETH/WH, pay 20 ETH, and can use electricity for 13.33 minutes and when used. The total amount of electricity will be cut off.
- Case 5: In the Tender Offer Competition, when the electricity in the system is insufficient, Houses A and B cannot make the Tender Offer, while Houses B and C can use electricity. However, the amount of electricity is sufficient only for one's use. There is no offer to sell into the system.

Table 6 The comparison of this research to other relevant studies

Features	Mateo [25]	Wayes [38]	Yi [39]	Kaixuan [40]	Meeuw [21]	Li [14]	Our Work
Blockchain Base	X	X	✓	✓	✓	✓	✓
Public Platform	X	X	✓	n/a	✓	✓	✓
Microgrid	X	X	X	X	✓	✓	✓
Battery Storage	X	X	X	X	✓	X	✓
Open Source	n/a	✓	n/a	X	✓	✓	✓
Double Auction	X	X	X	✓	X	X	✓
Energy Balance	X	✓	X	X	✓	✓	✓
Smart Meter	✓	✓	X	X	✓	X	✓
Lora Wan	X	X	X	X	✓	X	✓
Prepaid Payment	✓	X	X	X	X	X	✓
Implementation	X	X	✓	X	✓	X	✓
IoT control via Smart Contract	X	X	X	X	X	X	✓

5 Discussions

This research has complemented the Peer-to-Peer trading system in various aspects. For example, the use of Blockchain technology is inconsistent with IoT devices that enhance IoT security. Also, Lora Wan technology [35] improves wireless communication capabilities for greater transmission distance and security. Importantly, using a prepaid payment system makes the billing system less complicated while minimizing operating costs when compared to the postpaid system. The Double Auction [36] auction system is a fair marketing mechanism for both buyers and sellers. Neither side has any advantages or disadvantages. Besides, software implementation costs [37] benefit both beginners and business developers. However, we have compared them to other relevant studies, as shown in Table 6.

6 Conclusion, Limitation and Suggestion

6.1 Conclusion

The electricity trading system in Thailand is centralized and has a single buyer. Although the technology of electricity generation from solar energy is more advanced and cheaper, electricity consumers in the past could become electricity producers at the same time. The sale of electricity, on the other hand, cannot be done independently. Today, electricity trading using blockchain technology is relatively rare, and it is a closed technology that is hardly used in Thailand. In this research report, a model for P2P electricity

trading using blockchain technology is presented in the hope that it can lead to a free electricity trading model. Many cutting-edge technologies are included in the model, such as Laura Wan communication, dual auction, prepayment system, and so on. The researchers divided the system structure into four layers and demonstrated the interconnection of data at all levels. The proposed model was tested on real electrical equipment. We have tested both in the case that the amount of electricity in the system is sufficient and insufficient to supply electricity. The test results were very successful as intended. The results of this study will help those who are studying or planning to develop a blockchain-powered trading system. Help the reader understand each part of the structure well from start to finish. This will lead to a more complete development of buying electricity in the microgrid system in the future and as an alternative to solving the monopoly problem of a single buyer.

6.2 Limitation and Suggestion

6.2.1 Limitation

Although the results were satisfactory, the study still had some limitations: The experiment was conducted on only four houses in the test environment, and all four houses were adjacent to each other. This is due to the fact that it is still far from the type of electricity trading that is generally applicable. Due to the difficulty of conducting tests in real environments in terms of test site and equipment, as well as the cost of conducting the experiments, the studies were conducted in a relatively limited test environment so that this research could lead to practical applications. Further studies should be conducted in tests with more than 4 houses, up to N houses. Furthermore, what is the relationship between controlling estimated electricity generation and the actual amount of electricity that can be used? What is the impact of real-time auctioning on the overall system with a large number of homes? Results are not available for any of these studies. If there are complete conclusions from the above experiments, this should help complete the research results. This will be investigated by the researcher in the next step.

6.2.2 Suggestion in technical terms

According to Table 6, this research has added several test factors compared to other relevant research. However, this research still has some limitations that require further studies and improvements in various aspects: the number of houses used for testing is only 4, which is relatively minor. In addition, the time it takes for the test was as short as a few hours, while the load

used to represent electricity is a fan and light bulbs, while each house is located in the same area. These are all limitations of the research experiment. If experiments can be performed by elements that transcend the limitations above, we believe that the research outcomes will be perfectly completed. Below are some suggestions and considerations for further study:

Data communication: The connection with the MQTT Protocol signal can overcome faster communication. Meanwhile, if it is encrypted before transmission of the MQTT, it will increase communication security [41]. In terms of Lora signals, considerations regarding the location and direction of the antenna, including limitations that may affect the way of signal transmission.

Blockchain technology: In this study, the Ethereum Blockchain was used as the platform and consensus was used as a proof of work (POW) type, which may have limitations on processing speed if there are many nodes and data. Besides, the difficulty of decryption, e.g. [42], is increasing in other ways. Presently, Ethereum has developed a new version with a Proof of Stake (POS) consensus, which is likely to fix the mentioned limitations.

Smart Contract: The smart contract used in this system has been made in elementary conditions, intended to test the system's basic functionality. If it is applied, it should consider other related conditions such as tax deduction and exchanging money with other currencies.

6.2.3 Suggestion in business terms

The results of this study can be applied in Thailand to small-scale applications such as microgrids with power generation using solar energy, wind energy, biomass, etc. A wide application is not possible at present due to many obstacles, such as the current system being centralized with a single buyer. Furthermore, the law does not yet permit public free trade. Therefore, this system is only suitable for rural areas such as mountainous regions or islands. Areas without electricity supply from large utilities. It is a closed group in a village with a small number of houses. It could be a good starting point for P2P power trading in Thailand.

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