Evaluation of Community Peer-to-Peer Pricing Strategies in Thailand Perspective

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ARTICLE INFO

Article history:
Received: 26 September 2019
Revised: 19 March 2021
Accepted: 26 June 2021

Keywords:
Peer-to-peer (P2P) pricing method
Participatory method
Multi-level energy transaction method
Microgrid
Community grid
Energy trading

ABSTRACT

This paper analyzes the peer-to-peer (P2P) pricing methodologies used in the community microgrid-based trading mechanism. The analysis is carried out in the context of Thailand to study the possibility of the P2P market in Thailand. Per day saving in the electricity bill of a peer or a community will decide the effectiveness of the pricing method. However, each pricing strategy has its fundamental basis, so the comparison must be made relative to the objective of the formation of the market. Two price-based trading methods, participatory and multi-level trading, are analyzed from the local perspective; the participatory approach is mainly focused on community benefit rather than the individual. In this method, the ratio of the community's total power surplus/deficit to the sum of individual power surplus/deficit will decide the price of electricity to be transacted. Multi-level P2P introduces the P2P market model in a small community to a progressively larger level. Pricing depends mainly on the simple supply-demand principle of economics. The available power-to-demand ratio decides the electricity rate at any time. The result obtained from the study suggests that the multi-level trading method is the more successful pricing method over the participatory method as it results in higher savings for a prosumer. However, it is more complicated than a participatory model. The result also shows that the saving achieved is not a significant amount. Despite that, it presents the trend of saving capability, so with the proper policies and investment P2P trading market could be established soon.

1. INTRODUCTION

Recently, the deregulation of the electricity market has allowed for the development of a concept known as unbundling. Generally, three functional segments comprise the electricity market: generation, transmission, and distribution. In addition, the utility policy permits private sector involvement in the electric market. Private sector participation is encouraged, and the utility can implement bidirectional energy trading due to tremendous technological advancements. For example, a small household consumer can be considered a prosumer energy generation unit. Households can generate electricity using locally accessible renewable resources and sell the exceed to the main Grid. This scenario is called a prosumer-based decentralized market paradigm [1]. The most advantageous strategy for prosumer-based energy trading [2] is peer-to-peer (P2P) energy trading.

The peer-to-peer (P2P) concept has been around for a decade and is still being researched [3]. The Brooklyn microgrid project is the first significant achievement in this field [4]. The key feature of the P2P concept is the management of locally produced power within the community. Like the P2P concept, a distribution network can be divided into smaller functional power generation groups, each serving a minor area or location. That group may behave precisely as the power grid does. A microgrid is a term used to describe such groups. A microgrid, on the other hand, can include an even smaller unit known as Nanogrids. Each unit includes generation facilities, primarily renewable energy resources, and load. The total generation capacity is expected to meet the load demand. If this fails, power from the distribution grid will assist in stabilizing the system [5].

Peer-to-peer energy trading requires secure and efficient communication facilities, a fully automated distribution grid, a bilateral energy meter, an efficient clearing agent, and socioeconomic considerations [6]. The peer-to-peer energy trading concept was first introduced through a clearing mechanism based on contracts. Using the decentralization and distributed generation facility, the P2P trading model is two grid parties agreeing to purchase and sell the electricity for a specific period at a specific price. However, it lacks the flexibility of trading on a free market because the price will only change once the contract has expired. A multi-bilateral

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P2P trading concept overcame the shortcomings of the previous method. There are numerous participants (peers) in the P2P market. A buyer can purchase the cheapest electricity from the provider at any time. Primarily, it is available for supply for a brief period, typically a day or an hour in advance.

The community P2P concept has been extensively researched for the past few years. Many cost allocation models are proposed based on various factors [7],[8]. Three distinct pricing methods have been considered [5]. However, each model employs a different mode of cost calculation based on various parameters. No pricing method is widely accepted. To date, no fully-fledged commercial operating market has been established. For the community P2P concept, power is managed within the community, and surplus power is exported to the other community grid [9].

Each market model employs a unique pricing strategy; consequently, their outcomes will vary. With a controlling mechanism that limits the quantity and timing of power flow, the competitiveness and fairness of some methods may be high. Despite this, it requires less infrastructure than other methods, making it more suitable for residential microgrids. The fluctuating supply and demand for electricity directly impact the price of electricity, rendering specific methods extremely competitive. It demands a secure communication channel between the different levels and prosumers.

Some nations, including the United States, Australia, the United Kingdom, and the Netherlands, are developing prototypes for the P2P market. In this scenario, evaluating the various market models in light of the local environment is reasonable. This paper evaluates the effectiveness of the market mentioned above model in terms of daily electricity bill savings compared to the current grid transaction in Thailand. The assumption is that the presence of all necessary infrastructures has the potential to serve as a market model candidate for further application in Thailand.

2. COMMON MARKET MODELS

2.1 Collaborative Model (CM)

The purpose of CM is to facilitate increased collaboration and energy trading between all the households in the community. The conditions are that the amount of electricity each family requires is unique, and their peak demand occurs at different times of the day. Therefore, the power generated by prosumers is utilized inside the community to meet the energy demand. Trading occurs at the entire community level, meaning that the electricity rate is computed at the community level rather than considering individual households' supply and demand [7]. Instead of focusing on lowering each customer's bill, this strategy's primary objective is to reduce the overall cost of providing electricity to an entire community by making better use of the resources that are already there.

2.2 Multi-level Transaction (MT)

The P2P community can typically communicate with the other peers through the community controller or manager. The multi-level transaction intends to facilitate multi-level energy trading between a community with a smaller population, a larger population, and the Grid. This strategy reduces the individual prosumer's expenses [9].

2.3 Auction Based Clearing (ABC)

For the ABC trading market, each prosumer submits bids for the selling and the buying prices based on their prior experience and (generally an hourly or daily rate). According to predefined guidelines, the market declares the actual rate. This strategy's primary objective is to maximize both the sellers' and the buyers' profits in the community. Recently, the game-theoretic method [10] and the double-side auction [11] method are the two most frequently employed auction algorithms when analyzing the P2P market.

2.4 Existing P2P market in the world

2.4.1 Power Ledger

It is a startup company based in Perth working to implement the P2P market [12]. This business's trading mechanism is based on the blockchain model. This company digitally measures each participant's solar energy and the potential buyer's load demand. The platform then converts this energy into virtual currency and facilitates buyer transactions. Ultimately, purchasers will pay the amount in actual cash to the offeror.

2.4.2 Lo3 energy

Lo3 Energy is a startup company in southern Australia employing a market model based on auctions. The Lo3 energy concept is the continuation of the Brooklyn experiment. In addition, their power transactions are possible via mobile applications. Lo3 Energy conducted numerous projects to promote the use of green electricity in the United States and many European nations [13].

2.4.3 Sonnenflat

Sonnenflat is an example of a P2P market organized similarly to a load-sharing system. Before a business can participate in a load-sharing type of P2P market, it must install solar PV equipment with a capacity greater than 5 kilowatts and pay a monthly subscription fee ranging from $30 to $50. Under the terms of the subscription plan, all forms of life must contribute to pooling their solar energies. In order to reduce line congestion and maximize the use of distributed energy resources, a P2P market that employs load-sharing focuses primarily on storing and sharing energy [12].

2.4.4 Transactive Grid

Transactive grid is a trading model developed from a Brooklyn-based community electricity network. For this model, a single community can buy or sell electricity automatically to another community using the blockchain method with suitable software and hardware. At the community microgrid level, a transactive grid model is the most applicable work [5].

2.4.5 Vandebron

Vandebron is a trading market model for consumers in the Netherlands. For this trading model, consumers can purchase their electricity directly from many wind turbine power generations installed on farms through an electricity trading market currently operating in the country. The consumer can prioritize the generating unit from which they wish to purchase electricity based on the location of the generating unit and the type of supply [14].

3. METHODOLOGY

3.1 Participatory Method

Participatory Method is the most straightforward pricing method for electricity. The entire community is the utility's largest consumer. Additionally, each entity within the community contributes to the power company's bill. All members of the community share their generated energy. The Grid satisfies the community's demand, which is still greater than its generation.

Similarly, if each community has excess energy, it can sell to the utility primary grid at the prescribed rate. This pricing structure prioritizes the community's welfare over the market model based on profits. The cost of electricity will decrease as more members of the community share the energy generated, which will result in a decrease in the cost of energy for each member and a total reduction in the cost of energy for the community.

Furthermore, from the internal view of the community, the participatory method is a trading model of an independent conventional grid having its own buying and selling rates.

The following describes how to calculate such a price. Consider the community with n households with power generating units, i.e., PV, D_t is the entity's instantaneous demand at time t, and G_t is its generation capability. For individual members, The daily demand is determined as follows.

$$D_i = [D_i^1, D_i^2, D_i^3, \ldots D_i^T] \quad i \in [1,2,3 \ldots n] \tag{1}$$

where, D_i = the prosumer i load demand and T = total period, 24 for one day.

Similarly, a prosumer's hourly generation is

$$G_i = [G_i^1, G_i^2, G_i^3, \ldots G_i^T] \quad i \in [1,2,3 \ldots n] \tag{2}$$

$M_i(t)$ represents the simultaneous mismatch power between a prosumer's supply and demand at time t, as shown in equation (3).

$$M_i(t) = \min(D_i(t), G_i(t)) \tag{3}$$

$P_{i,\,Buy}$ represents the prosumer's importing power due to a power generation deficit, as shown in equation (4).

$$P_{i,Buy} = D_i(t) - M_i(t) \tag{4}$$

Equation (5) indicates that the surplus power generation must be exported to the Grid.

$$P_{i,Sold} = G_i(t) - M_i(t) \tag{5}$$

As shown in equation (6), $E_{buy,\,total}$, and E_{Sold} represent the total energy a community purchases from the Grid and sells back to it.

$$\begin{aligned} E_{Buy,total} &= \sum_{i=1}^{n} \sum_{t=}^{24} P_{DIF}(t) \\ E_{Sold,total} &= \sum_{i=1}^{n} \sum_{t=}^{24} P_{SUR}(t) \end{aligned} \tag{6}$$

The electricity buying and selling prices, C_{GBR} and C_{GSR}, represent the utility company issues. In the case of direct grid trading, equation (7) represents the electricity cost of an individual prosumer.

$$C_i^{DG} = (\textstyle\sum_{t=1}^{24} P_{i,Buy}(t) \cdot \Delta t) \cdot C_{GBR} - (\sum_{t=1}^{24} P_{i,Sold}(t) \cdot \Delta t) \cdot C_{GSR} \tag{7}$$

When considering power sharing within a Microgrid, the instantaneous power balance should be determined for the entire community instead of each individual. The instantaneous power balance indicates the self-consumption of the community's power generation (shared PV generation). It is expressed as,

$$M_i(t) = \min(\textstyle\sum_{i=1}^{n} D_i(t), \sum_{i=1}^{n} G_i(t)) \tag{8}$$

The combined power brought from the Grid (after sharing), represented by $P_{GB}(t)$ and total community sales denoted as $P_{G_n}(t)$. $P_{GB}(t)$ and $P_{G_n}(t)$ are determined as follows,

$$P_{GB}(t) = \textstyle\sum_{i=1}^{n} D_i(t) - M_i(t) \tag{9}$$

$$P_{GS}(t) = \textstyle\sum_{i=1}^{n} G_i(t) - M_i(t) \tag{10}$$

In terms of energy

$$E_{GB} = \textstyle\sum_{t=1}^{24} P_{GB}(t) \cdot \Delta t \tag{11}$$

$$E_{GS} = \textstyle\sum_{t=1}^{24} P_{GB}(t) \cdot \Delta t \tag{12}$$

For the P2P energy trading scenario, each community members share their electricity generation capability, and the sum of each member consumed and exported electricity will always remain higher than the community electricity consumed and exported.

The community energy trading manager will now calculate electricity purchasing and selling rates. C_{MGBR} is the purchasing price, and C_{MGSR} is the selling price.

$$C_{MGBR} = C_{GBR} \frac{E_{GB}}{B_{Buy,total}} \tag{13}$$

$$C_{MGSR} = C_{GSR} \frac{E_{GS}}{B_{Sold,total}} \tag{14}$$

Finally, the new electricity cost for a prosumer belonging to the modified rate or the P2P rate can be calculated as

$$C_i = (\sum_{t=1}^{24} P_{i,Buy}(t) \cdot \Delta t) \cdot C_{MGBR} - (\sum_{t=1}^{24} P_{i,Sold}(t) \cdot \Delta t) \cdot C_{MGSR} \tag{15}$$

3.2 Multi-level transaction

As shown in Fig. 1, Nanogrid is considered the basic unit with various loads, and each nanogrid has its electricity generation. The demand and generation profiles are similar to equations (1) and (2). To determine whether a household is a consumer or producer at a time, t. S_i^t is considered. The minimum value of D_i^t and G_i^t is considered to be S_i^t as described in equation (16).

$$S_i^t = \min(D_i^t, G_i^t) \tag{16}$$

Power to be imported and exported by a nanogrid can be calculated as

$$P_{i,im}^t = D_i^t - S_i^t \tag{17}$$

$$P_{i,ex}^t = G_i^t - S_i^t \tag{18}$$

Demand and supply, a fundamental economic principle, must be followed for the market pricing method to operate sustainably. Therefore, the amount-to-demand ratio (SDR), which primarily determines the rate of electricity, is given by

$$SDR^t = \frac{TPG^t}{TPD^t} \tag{19}$$

The SDR varies, belonging to the fluctuations in solar power generation and load demand resulting in changes over time.

3.3 Pricing strategy among various level

To begin, NGOs calculate whether there is an excess or shortage of electricity at time t by subtracting available generation from required demand. Net power (NP) is calculated by dividing available generation by required demand.

$$NP_i^t = D_i^t - G_i^t \tag{20}$$

Idealistically, the NGOs should be able to determine the energy rate that applies to their region. Despite this, it has a small power network and few participants. The price set by the superior controller (in this case, CEM) cannot be significantly deviated from at this pricing level. The fundamental entity is the main factor to consider when assessing nanogrid.

NGOs send their data upstream to the CEM controller because the multi-level P2P paradigm is built on level coordination. CEM calculates the total available electricity and energy demand by combining the data transmitted by each NGO at time t. TPE is the total available electricity for sale, whereas TPD is the total electricity demand from the next-level market. TPE and TPD are expressed as follows:

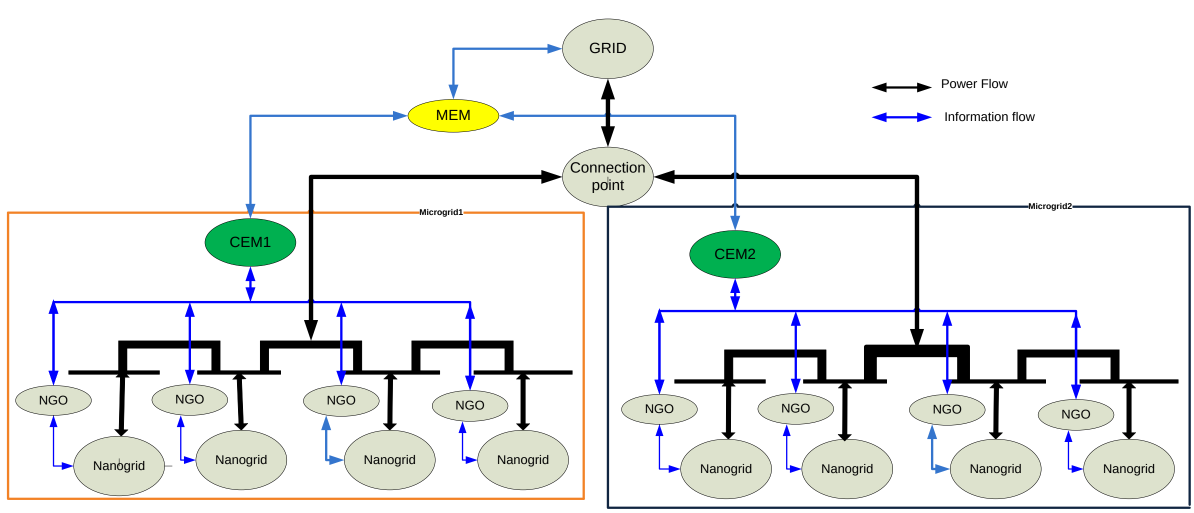

Fig.1. Block Diagram of Multi-level Transaction method Comprising Two Microgrid and Four nanogrids per Microgrid

$$TPE^{i} = -\sum_{i=1}^{n} NP_i^t \quad ; NP_i^t < 0 \tag{21}$$

$$TPD^{t} = -\sum_{i=1}^{n} NP_i^t \quad ; NP_i^t > 0 \tag{22}$$

Since a higher-level trading market exists in the system, a microgrid cannot freely define the trading cost. However, the trading cost must satisfy the cost determined by the trading partner. So, the CEM again determines the net residual power in each microgrid, similar to the NGO. Then, a power mismatch (PM) is defined to avoid confusion.

$$PM^{t} = TPD^{t} - TPE^{t} \tag{23}$$

MEM is the ultimate controller that allows grid interaction and finally receives data from CET. MEM then calculates, sells, or borrows surplus power from the Grid. *TPE* and *TPD* at the moment *t* is given;

$$TPE^{t} = -\sum_{j=1}^{m} NP_j^t \tag{24}$$

$$TPD^{t} = \sum_{j=1}^{m} NP_j^t \tag{25}$$

Now, the SDR of the entire system at time *t* is calculated using,

$$SDR^{t} = \frac{TPE^{t}}{TPD^{t}} \tag{26}$$

However, the rate of grid exchange remains constant over time even though the internal price of the system shifts in tandem with the SDR. α_{buy} and α_{sell} are the rates of grid buying and the rate of grid selling, respectively.

The internal energy rate defined by MEM can be represented as

$$\beta = \{\beta_{Buy}^1, \beta_{Buy}^2, \ldots, \beta_{Buy}^{24}; \beta_{Sell}^1, \beta_{Sell}^2, \ldots, \beta_{Sell}^{24}\} \tag{27}$$

The Grid and MEM prices must always meet the following requirements for a sustainable economic benefit derived from the P2P market.

$$\alpha_{Sell} \le \beta_{Sell} \le \beta_{Buy} \le \alpha_{Buy} \tag{28}$$

According to Paudel (2018), the fundamental law of supply and demand, also known as SDR and the relation described above, serves as the foundation for MEM's approach to rate determination. Then

$$\beta_{Sell}^t = \begin{cases} \dfrac{\alpha_{Sell}\alpha_{Buy}}{(\alpha_{Sell} - \alpha_{Buy})SDR^t + \alpha_{Sell}} & ; 0 \le SDR^t \le 1 \\ \alpha_{Sell} & ; SDR^t > 1 \end{cases} \tag{29}$$

$$\beta_{Buy}^t = \begin{cases} \beta_{Sell}^t SDR^t + \alpha_{Buy}(1 - SDR^t) & ; 0 \le SDR^t \le 1 \\ \alpha_{Sell} & ; SDR^t > 1 \end{cases} \tag{30}$$

The price rate that MEM calculates serves as the boundary limit for individual microgrids or, more specifically, CEM. CEM arrives at its internal pricing rate by combining its own SDR with the price rate that MEM has given it. SDR of m^{th} Microgrid is given by,

$$SDR_m^t = \frac{TPE_m^t}{TPD_m^t} \tag{31}$$

Similar to the MEM, the CEM price must agree with the following relationship for the operation of a microgrid to remain profitable.

$$\beta_{Sell} \le \gamma_{Sell} \le \gamma_{Buy} \le \beta_{Buy} \tag{32}$$

CEM uses the rate obtained from MEM to determine a new price sequence compatible with the relationship above. Therefore, the CEM internal pricing sequence is represented by the following:

$$\gamma_{m,Sell}^t = \begin{cases} \dfrac{\beta_{Sell}^t \beta_{Buy}^t}{(\beta_{Buy}^t - \beta_{Sell}^t)SDR_m^t + \beta_{Sell}^t} & ; 0 \le SDR_m^t \le 1 \\ \beta_{Sell}^t & ; SDR_m^t > 1 \end{cases} \tag{33}$$

$$\gamma_{m,Buy}^t = \begin{cases} \gamma_{m,Sell}^t SDR_m^t + \beta_{Buy}^t(1 - SDR_m^t) & ; 0 \le SDR_m^t \le 1 \\ \beta_{Sell}^t & ; SDR_m^t > 1 \end{cases} \tag{34}$$

Finally, the electricity bill for each nanogrid under various trading scenarios is calculated as follows,

3.3.1 The Peer to Grid trading

In this instance, a peer transacts directly with the Grid; therefore, the grid exchange rate applies.

$$C_{P2G}^i = \left(\sum_{t=1}^{24} P_{i,im}^t(t) \cdot \Delta t\right) \cdot \alpha_{Buy} - \left(\sum_{t=1}^{24} P_{i,ex}^t(t) \cdot \Delta t\right) \cdot \alpha_{Sell} \tag{35}$$

3.3.2 The single-stage P2P trading

$$C_{SP2P}^i = \left(\sum_{t=1}^{24} P_{i,im}^t(t) \cdot \Delta t\right) \cdot \beta_{Buy}^t - \left(\sum_{t=1}^{24} P_{i,ex}^t(t) \cdot \Delta t\right) \cdot \beta_{Sell}^t \tag{36}$$

3.3.3 The Multi-level P2P trading

$$C_{HP2P}^i = \left(\sum_{t=1}^{24} P_{i,im}^t(t) \cdot \Delta t\right) \cdot \gamma_{m,Buy}^t - \left(\sum_{t=1}^{24} P_{i,ex}^t(t) \cdot \Delta t\right) \cdot \gamma_{m,Sell}^t \tag{37}$$

4. SIMULATION SETUP AND RESULTS

The simulation considers two different microgrids, MG1 and MG2, each comprised of five and three nanogrids, respectively. Each nanogrid contains a solar generation facility, and the PV generation profile is determined by first standardizing the actual solar data obtained from PEA Thailand. For the simulation, data are taken from eight different days in 2019 so that the eight nanogrids can be accurately represented. Similarly, the load profile used in this work is the normalized TOD data obtained from the PEA for various businesses and distribution transformers in several different localities.

The two microgrids, MG1 and MG2, are depicted in Figures 1 and 2, respectively. A presumption is made regarding the selling and buying prices of the Grid. The utility is anticipated to purchase energy at a rate of 2,71 Thai baht (THB) (the average selling price of electricity by the electricity generation authority of Thailand to the provincial electricity authority (PEA)) [15]). There is a broad range of selling prices for the utility's various consumer groups. As a result, the price is arbitrarily set at 7 THB, the rate applicable to Thailand's renters.

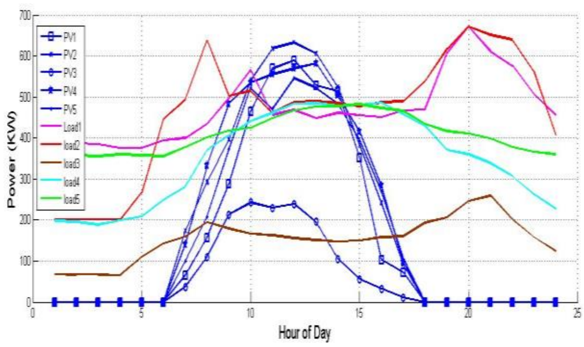

Fig.2. Simulation Data of Microgrid 1.

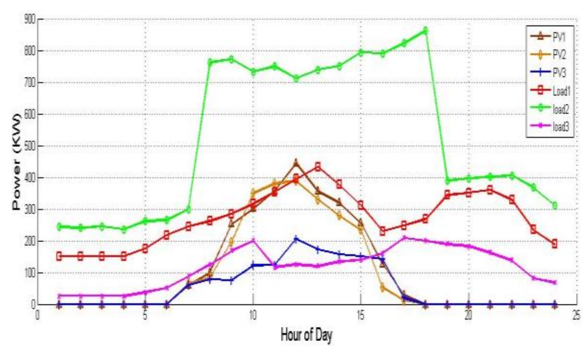

Fig.3. Simulation Data of Microgrid 2.

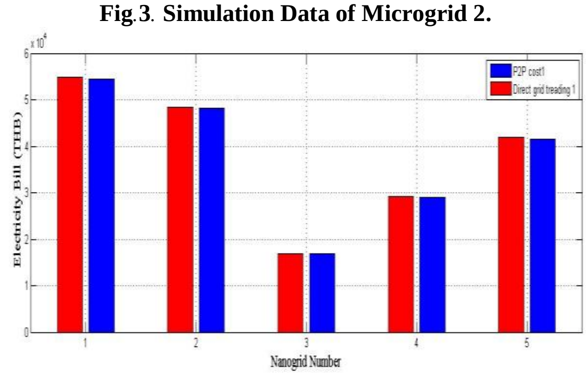

Fig. 4. Overall Cost of Microgrid 1 in Participatory Model.

Figures 4 and 5 depict the total cost of microgrids 1 and 2, respectively, in two scenarios, direct grid trading and peer-to-peer trading, using the model of the participatory market. It was determined that the total cost of electricity is lower in the P2P scenario than in the indirect grid trading scenario for all nanogrids within microgrids 1 and 2, except nanogrid three within microgrid 2. However, nanogrid 2 of microgrid 2 has the most significant savings due to the nature of its pricing strategy. The participatory method determines transaction prices based on the community's total power generation and supply. In this scenario, the peer with the highest share will benefit more, while the peer with the lowest share will suffer. The total electricity cost for microgrid 1 in indirect grid trading mode is 191,114 THB, whereas the total electricity cost for microgrid 1 in P2P mode is only 1089 THB less than the previous case. Similarly, in Microgrid 2, the P2P scenario using the participatory market model yields a total savings of 975 THB. The negligible savings may be attributable to lower PV penetration, i.e., the absence of sellable power.

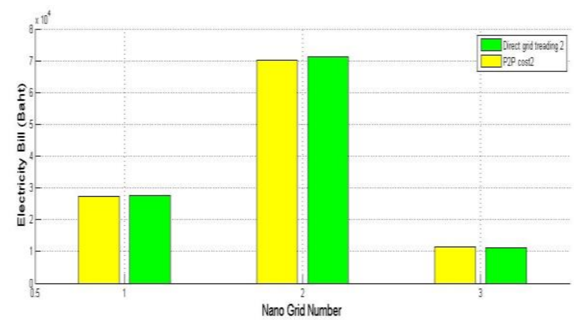

Fig.5. Overall Cost of Microgrid 2 in Participatory Model.

4.1 The Multi-level Energy Transaction Model

The MEM, CEM1, and CEM2 electricity rates are depicted in Figures 6-8, respectively. The price fluctuation takes place between 9:00 am and 3:00 pm. This is due to the availability of sufficient solar power in that range, or SDR, on a scale from 0 to 1 during that period. In contrast, when SDR is less than one, the buying and selling price equals the Grid's selling price. In the case of single-stage trading, peers can only transact within their own Microgrid, eliminating the possibility of maximizing profit by selling excess power to a Microgrid in need of power.

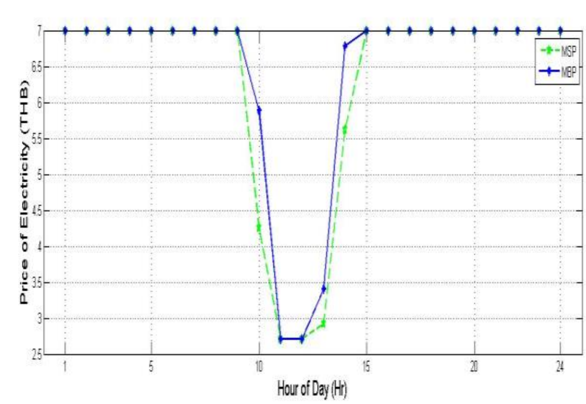

Fig.6. MEM Pricing in Multi-level Trading.

Table 1. Overall Per Day Electricity Bill of Each Nano Grid in Various Pricing Scenarios

	Electricity Bill (THB) in Microgrid 1						Electricity Bill (THB) in Microgrid 2			
	NG1	NG2	NG3	NG4	NG5	Total	NG1	NG2	NG3	Total
Direct Grid Trading	54856	48453	16844	29129	41838	191120	27662	71176	11126	109964
Participatory	54485	48179	16796	29027	41544	190031	27404	70153	11432	108989
Single Stage P2P	54574	48275	16540	28560	41663	189612	27375	70410	10910	109695
Multi-Stage P2P	54411	48275	16510	28560	41663	189419	27631	66205	10941	104777

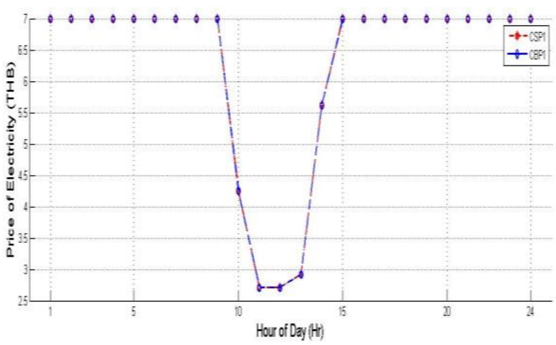

Fig.7. CEM1 Pricing in Multi-level Trading

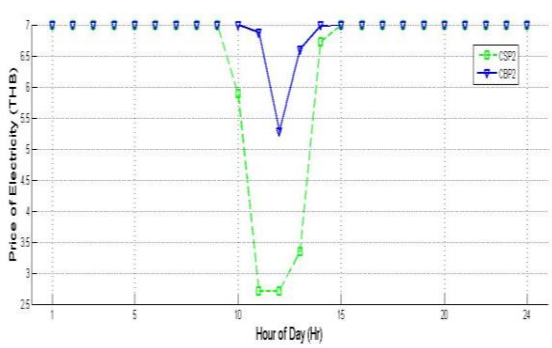

Fig.8. CEM2 Pricing in Multi-level Trading.

Consequently, the excess power must be sold to the Grid for a low price; on the contrary, the power deficit microgrid must buy grid power at a higher rate. It results in a two-way loss. This phenomenon is observed in Table 1. In both cases, NG2 and NG5 of MG1 have the same amount because they neither have any excess or deficit power to participate in the multi-level market. However, the cost of the remaining nanogrids of MG1 is reduced. Consequently, the overall price of MG1 decreased to 189,612 THB in the case of single-stage P2P.

In addition, a decline was noticed in the case of the multi-level P2P, which led to 189,419 THB, the least amount of money generated by any of the instances. Compared to the single-stage transaction, the multi-level trading amount that NG1 and NG2 have access to in MG2 is marginally more significant. It may be because of the increased availability of power in MG2, caused by imports from MG1, and the increased competition, which caused NG1 and NG3 to earn less money. On the other hand, the high downfall cost of NG2 caused the overall price of MG2 to be the lowest it could be in the multi-level trading scenario.

5. CONCLUSION

The concept of peer-to-peer (or P2P) energy trading is widely regarded as the industry's future direction. The Royal Thai Government has also actively supported the peer-to-peer (P2P) exchange concept in recent years. This study aimed to investigate the global P2P scenario and analyze the efficiency of pricing strategies used in community P2P. It was discovered that the multi-level trading mechanism is more fruitful than the single-stage P2P or participatory P2P model because this model results in a higher saving to the prosumer. This discovery was made after comparing it to other P2P and P2P models. Because grid buying and selling rates are similar to one another and because the PV generation data for an enterprise is assumed based on the actual generation profile of a solar farm, the amount of money saved in this research does not represent a significant amount. However, the research indicates that P2P can be implemented in Thailand with the appropriate planning and policies and that the multi-level transaction pricing method will be the most suitable option for community P2P.

ACKNOWLEDGMENT

The Suranaree University of Technology supports this research work. The authors are indebted to the University for financial and technical assistance.

REFERENCES

[1] Van der Schoor, T., and Scholtens, B., 2015, "Power to the People: Local community initiatives and the transition to sustainable energy", *Renewable and Sustainable Energy Reviews*, Vol. 43, pp. 666-675.

[2] Giotitss, C., Pazaitas, A., and Kostakis, V., 2015, "A peer to approach to energy production", Technology in Society, Vol. 42, pp. 28-38.

[3] Beitollahi, H., and Deconinck, G., 2007, "Peer-to-peer networks applied to power grid", *In Proceedings of the international conference on risks and security of internet and system.*

[4] Mengelkamp, E.; Garttner, J.; Rock, K.; Kessler, S.; Orsini, L.; and Weinhardt, C., 2017. "Designing microgrid energy markets: A case study: the Brooklyn microgrid", *Applied Energy* 105:870-880.

[5] Zanga, C., Wua, J., Longa, C., and Chenga, M.ม 2016, "Review of existing peer to peer energy trading projects", *In proceeding of The 8th international conference on applied energy ICAE2016.*

[6] Morysten, T., Farrell, N., Darby, S. J., and McCulloch, M. D., 2018, "Using peer to peer energy trading platforms to incentivise prosumers to form federated power plants", *Nature Energy*, Vol. 3, No. 2, pp. 92-101.

[7] Long, C., Wu, J., Zang, C., Thomas, L., Cheng, M., and Jenkins, N., 2017, "Peer to peer energy trading in community microgrid", *In proceeding of IEEE power and energy society general meeting.* Chicago, IL, USA.

[8] Zang, C., Wu, J., Cheng, M., Zhou, Y., and Long, C., 2016, "A bidding system for peer to peer energy trading in a grid connected Microgrid", *In proceeding of applied energy symposium and forum, REM2016: Renewable energy Integration with Mini/Microgrid.*

[9] Paudel, A., and Beng G.H., 2018, "A hierarchical peer to peer energy trading mechanisms for residential microgrid distribution systems", *In proceeding of IEEE power and energy society general meeting (PESGM)*, Portland, OR, USA, 5-10 Aug.

[10] Leong C.H., Gu, C., and Li, F., 2018, "Auction mechanism for P2P local energy trading considering physical constraints", *In the proceedings of 10th international conference on applied energy (ICAE2018).* Hong Kong.

[11] Faquiry, N.M., and Das, S., 2016, "Double-sided energy auction in Microgrid: equilibrium under price anticipation", *IEEE Access*, Vol. 4, pp. 3794-3805.

[12] N.D. can star Blue. Canstar Blue Pty Ltd. Accessed May 12, 2019. https://www.canstarblue.com.au/solar-power/P2P-energy-trading/.

[13] Energy, Lo3. 2018. Lo3 energy. Accessed May 22, 2019. https://lo3energy.com/.

[14] N.D. Van de Bron. Van de Bron energy B.V. Accessed May 14, 2019. https://vandebron.nl/energie.

[15] Electricity generating authority of Thailand, "*Annual report 2018*", pp 133.