POSSIBLE PEER-TO-PEER PRICING MECHANISMIN MICRO-GRID THAILAND

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Abstract - Peer-to-Peer (P2P) pricing mechanisms enable electricity trading between prosumers and nearby consumers in community Micro-Grid to support a power system's decentralization.This paper proposes the two possible pricing mechanisms for P2P electricity trading, i.e., bill sharing (BS) and auction mechanism (AM). Under both P2P schemes, prosumers can sell their excess electricity after self-consumption to obtain more income. At the same time, consumers can pay less electricity cost than participating in Thailand's solar incentive scheme (Net-metering with buyback). However, both P2P methods have different energy allocation and clearing price calculations, so they are discussed and compared with the Net-metering with buyback scheme.

Keywords - Peer-to-Peer Electricity Trading, Pricing Mechanism, Micro-Grid, Auction Mechanism.

I. INTRODUCTION

Thailand's power system is structured under an enhanced single buyer model, a centralized structure controlled by electricity authorities and energy regulators [1]. The system is currently transitioning to decentralization due to the increasing number of prosumers who produce electricity from Distributed Energy Resources (DERs), especially solar PV. As mentioned in the Thailand Power Development Plan (PDP) 2018, the solar power installation target was adjusted from 6,000 MW to 10,000 MW, including ground-mounted and rooftop projects [2, 3]. The plan represents the growth of solar PV installation in the upcoming years. Considering Thailand's solar policy, the first implementation was called "the adder scheme," launched in 2007 for solar farms at 8 Baht/kWh. The adder rate was decreased to 6.50 Baht/kWh in 2010 due to the oversubscribed producers and the impact of their PV generation pass-through costs to consumers [4, 5]. After that, the Feed-in-Tariff scheme (FiT) was introduced in 2013 for solar rooftops and solar farms. The incentive rates for solar rooftops are 6.16-6.96 in phase 1 and 5.66 – 6.85 in phase 2, while solar farms receive a fixed rate of 5.66 THB/kWh in phase 1 and 4.12 THB/kWh in phase 2.

From 2013 to 2015, under this scheme, the PV generation was repurchased at a fixed higher rate than retail electricity price to encourage PV installation. In the middle of 2016, the Self-Consumption Pilot Scheme was announced for Rooftop PV. For this scheme, the PV generation must be consumed on-site, then any excess will be fed back to the main grid without any monetary credits [6]. From May 2019, the Office of Energy Regulatory Commission (OERC) launched the new Net-Metering program for repurchasing the excess PV rooftop generation to the main grid. The incentive rate for private households is 1.68 THB/kWh with a target of 100 MW installed capacity, 30 MW in the Metropolitan area, and 70 MW in other provinces [7]. These demonstrate limitations and unattractiveness to decide on investment under this centralized market or Peer-to-Grid (P2G) scheme. Therefore, this paper aims to propose the possible price mechanisms for Peer-to-Peer electricity trading in Thailand, focusing on electricity trading in community Micro-Grid for Thailand's decentralized market structure, so the research objectives are derived as follows:

1. To propose pricing mechanisms for Peer-to-Peer electricity trading in Thailand's Micro-Grid.
2. To discuss the Peer-to-Peer schemes comparing to the Net-metering with buyback.

II. PEER-TO-GRID SCHEME

The current incentive scheme for repurchasing electricity produced from the solar rooftop projects in Thailand is Net-metering with buyback, a self-consumption scheme. As participants in this scheme, prosumers have to consume their productions before selling the excess electricity to the main grid at a fixed buyback rate (P_{sg}; THB/kWh) controlled by the Office of Energy Regulatory Commission (OERC). Moreover, the prosumers have to buy electricity from the main grid at the retail rate (P_{bg}; THB/kWh) when electricity is not sufficient [7]. As presented in Fig. 1 (a), prosumers need smart meters, which are bi-directional meters to measure energy import and export, whereas consumers can use electric meters to measure energy import as usual. Each metering data represents participants' roles as eitherseller or buyer. The energy import (Q_b^i; kWh) represents the energy demand whom a buyer i purchases from the main grid, whereas the energy export (Q_s^i; kWh) represents the energy supply whom a seller provides to the bulk

electricity grid. Under this scheme, the electricity authority plays the important roles as both a distribution system operator who manages electricity transfer through the distribution network (main grid) and a retailer who trades electricity with the customers directly. The retailer collects metering data and computes individual electricity cost ($Cost^i$; THB) and income ($Income^i$; THB) as described in eq. 1-2.

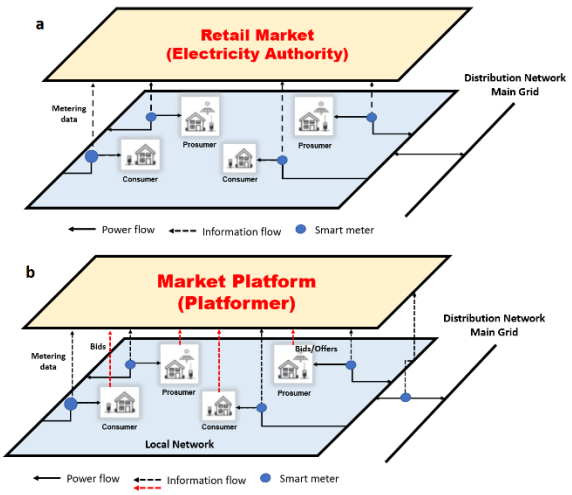


Fig.1. (a) Peer-to-Grid Scheme; (b) Peer-to-Peer Scheme.

$$Cost^i = P_{bg} \times Q_b^i \quad (1)$$

$$Income^i = P_{sg} \times Q_s^i \quad (2)$$

Therefore, the Net-metering with buyback shows an absolutely centralized form of electricity trading both market mechanism and price mechanism.

III. PEER-TO-PEER SCHEME

Figure 1 (right) shows the architecture of Peer-to-Peer (P2P) electricity trading, which was designed in the form of a community-based trading model to support the decentralization in the power market. Considering power flow, electricity transfers through the existing distribution network in community Micro-Grid, where connects to the distribution network owned by electricity authority at a point of common coupling (PCC). At the PCC point, a smart meter is installed to measure net electricity import and export between these two areas so that to balance demand and supply in the community Micro-Grid. Regarding the information flow, bids and offers from households (red dash lines) and the metering data from smart meters (black dash lines) are submitted to the market platform. A price mechanism is deployed to allocate trading quantity and compute the clearing price for each household. Hence, different price mechanisms deployed on the market platform produce different trading results. As participants in the P2P scheme, they agree on the platformer's price mechanism, responsible for maintaining the market platform and providing services to all households. This paper proposed two different P2P price mechanisms described below: Bill Sharing (BS) and Auction Mechanism (AM).

3.1. Bill Sharing (BS)

Bill Sharing, a P2P electricity trading, was designed in the concept of cost-sharing among participants in a trading system without order submission [8-10]. For this paper, the Bill Sharing was modified to allow buyers and sellers to submit their bids and offers to the market platform. After that, offers and bids are separately accumulated and sorted in descending and ascending prices, respectively. After the completion of the period, the platformer will then check the energy demand-supply balance, which possibly happens in 3 cases: i). supply equals demand, ii). supply surplus, iii). supply deficit. Clearing prices for all cases will be computed.

i) Supply equals demand.

Total power supply from sellers meets the total demand in the trading system as shown in Fig. 2 ($\sum_{i=1}^{n_b} Q_b^i \sum_{i=1}^{n_s} Q_s^i$; where n_b number of buyers and n_s = number of sellers). All sellers and buyers have to trade electricity at a single clearing price ($P_{Cl,BS}$) calculated by the weighted average of individual offer prices (P_s^i) as shown in eq. 3. In this case, there is no excess supply and demand.

$$P_{Cl,BS} = \frac{\sum_{i=1}^{n_s} P_s^i Q_s^i}{\sum_{i=1}^{n_b} Q_b^i}. \quad (3)$$

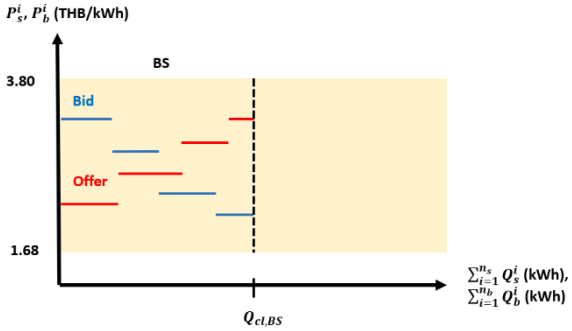


Fig.2. Bill Sharing (Supply equals demand).

ii). Supply surplus

Total power supply from sellers exceeds the total demand in the trading system as shown in Figure 3($\sum_{i=1}^{n_b} Q_b^i < \sum_{i=1}^{n_s} Q_s^i$; where n_b number of buyers and n_s = number of sellers).The sellers who own the balancing supply and all buyers have to trade electricity at a single clearing price ($P_{Cl,BS}$) calculated by the weighted average of individual offer prices (P_s^i) of the balancing supply as shown in eq. 4 ($\sum_{i=1}^{n_y} Q_s^i$; n_y number of sellers who own the balancing supply, $n_s = n_x + n_y$).

$$P_{Cl,BS} = \frac{\sum_{i=1}^{n_y} P_s^i Q_s^i}{\sum_{i=1}^{n_b} Q_b}; \sum_{i=1}^{n_y} Q_s^i = \sum_{i=1}^{n_b} Q_b^i. \quad (4)$$

The excess supply($\sum_{i=1}^{n_x} Q_s^i$; n_x number of sellers who own the excess supply),off

ered at a higherprice than the clearing price, will be sold to the grid at the price of P_{sg}.

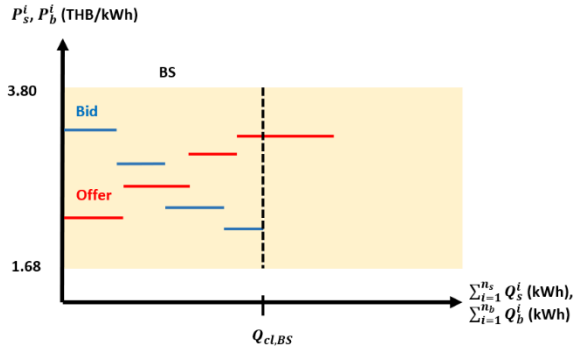


Fig.3. Bill Sharing (Supply surplus).

iii). Supply deficit

Total supply from sellers is not enough to cover the total demand in the trading system as shown in Fig 4 ($\sum_{i=1}^{n_b} Q_b^i > \sum_{i=1}^{n_s} Q_s^i$; n_b number of buyers and n_s = number of sellers). All sellers and the buyers who own the balancing demands ($\sum_{i=1}^{n_h} Q_b^i$; n_h number of buyers who own the balancing demands , $n_b = n_k + n_h$)have to trade electricity at a single clearing price ($P_{Cl,BS}$) calculated by the weighted average of individual offer prices (P_s^i) as shown in eq.5.

$$P_{Cl,BS} = \frac{\sum_{i=1}^{n_s} P_s^i Q_s^i}{\sum_{i=1}^{n_h} Q_b^i}; \quad \sum_{i=1}^{n_s} Q_s^i = \sum_{i=1}^{n_h} Q_b^i. \quad (5)$$

The grid power will match the deficit ($\sum_{i=1}^{n_k} Q_b^i$; where n_k number of buyers who own the excess demands) at the price of P_{bg}.

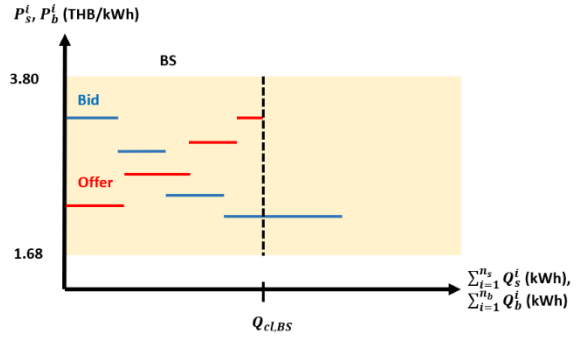


Fig.4. Bill Sharing (Supply deficit).

Under the Bill Sharing scheme, consumers pay less electricity cost. Prosumers obtain more electricity income than participating in the P2G scheme because the clearing price is computed by the weighted average of the offer prices at market balance. Thus, the prices are probably varied depending on the majority of offer prices submitted by prosumers. The excess supply or demand that cannot be mapped in the BS scheme will be sold by another scheme, such as the P2G scheme. Otherwise, there should be a storage system to charge and discharge for the excess supply and demand.

3.2. Auction Mechanism (AM)

Auction is commonly used in the process of buying or selling goods or services. Traditional auctions are typically used for the allocation of a single item. In the open ascending-bid, an auctioneer announces a good to all bidders who openly bid against one another with a higher price continuously until no bidder cannot make a higher bid. Hence, the highest bidder wins the auction at the final price. The auction for P2P electricity trading can be adopted to obtain the highest purchasing power. Continuous Double Auction (CDA) allows competition on both bidders and offerors for P2P electricity trading [8, 11-13]. An open order book is also used for recording the list of offers and bids submitted by sellers and buyers during the bidding period. After period closure, the platformer allocates, matches, and computes trading results publicly revealed on the market.

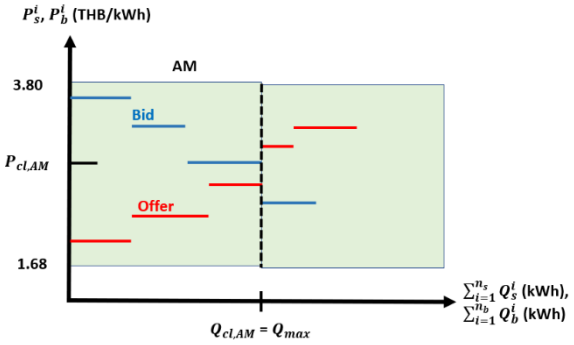


Fig.5. Auction Mechanism (AM).

However, the previous studies have different price mechanisms, for example, the lowest bid [11-12], the highest offer [8], and the average mechanism [13]. Thus, this paper would like to propose an Auction Mechanism (AM) in which the price mechanism is computed by the maximum executable volume and minimum imbalance method adapted from the Stock Exchange of Thailand (SET) [14]. After bids and offers arrive at the electricity market, all requests arrange in descending prices, while all offers arrange in ascending prices. The market will then calculate the maximum executable volume and its minimum imbalance to get a single clearing price ($P_{Cl,AM}$) for each auction round, which is the lowest bid price, as shown in Figure 5. Under the AM scheme, some prosumers and consumers can participate depending on quantity and price allocation. Although the AM scheme's trading quantity is less than in the BS scheme, all participants obtain the trading results following their preferences. Only consumers who had submitted the bid prices more than the clearing price and prosumers who had raised the offer prices less than the clearing price can participate in the AM scheme. The consumers are happy to buy at a lower price because they can get electricity at a lower price than expected. Likewise, the prosumers are also pleased to sell at higher prices for more income. The excess demand belongs to the consumers who

submitted bids with too low prices, and the excess supply belongs to the prosumers who submitted offers with too high prices. They will have to trade electricity under other schemes, such as the BS or the P2G scheme.

IV. CONCLUSION

Two different price mechanisms, Bill Sharing (BS) and Auction Mechanism (AM) were proposed to apply in Peer-to-Peer (P2P) energy trading for Thailand's community Micro-Grid. As participants in both P2P schemes, they get more benefits than participating in the Net-Metering with Buyback or Peer-to-Grid (P2G) Scheme. These two P2P schemes have different energy allocation and clearing price calculations. Under the BS scheme, trading results are computed based on demand-supply balancing and the majority of offer prices at market balance. In contrast, the AM trading results are allocated depending on quantity and prices, so participants get their results under their preferences. The prosumers are happy to sell electricity at a higher price, and consumers are also pleased to buy at a lower price than their submissions. However, the excess demand and supply, which are not traded under the auction mechanism (AM), can be transferred to a bill-sharing mechanism (BS) or peer-to-grid (P2G) scheme.

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