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A local distribution network management model for sustainably competitive electricity market

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Abstract

Many small power producers (SPPs) exist in the power market worldwide. Some of which established their owned grids to transport electricity to customers directly leading to the complexity in electricity market structure under multi-owned integrated distribution system. This paper aims to equilibrate a decision strategy to encourage the asset sharing of the distribution grids among the distribution owners and to introduce a conflict management model to avoid the employment of the complex wheeling methods to the various distribution owners of the combined system. A numerical simulation shows that the equilibrium point is on the strategy that the common asset must be shared among all players. Every network user is then at a level playing field with a fair and equitable responsibility to the distribution system based on their actual usages.

Keywords: Competitive market, distribution system, game theory, investor-owned utility, unbundling model

1. Introduction

At present, there are many small power producers (SPPs) emerging in the power market. In many countries, the small power producer exists as the business program that is sponsored by the government to promote the concept of Distributed Generation (DG). More SPPs would lead to an increase in competition in the power market. Meanwhile, some SPPs start to own distribution systems privately and then upgrade to be distribution investor-owned utilities (DIOUs). As a result, it turns out that the competition is not in the generations sector anymore. Some other SPPs hereby decided to build their own private grid and become the competitive DIOUs.

From the situation above, the DIOUs that own the distribution network are breaching the concept of 'Natural Monopoly' which could lead to an over-investment of the assets. Moreover, it will create further complexity to the competitive retail market in the future, and hence lead to the difficulty in handling some important issues such as distribution network pricing, wheeling charges, etc. The similar situation exists in The United States power market at the utility-to-utility level [1]. This could also happen in any areas that attempt to implement the Micro Grid (MG) such as in Cambodia [2] when the Mini Grids start trading with each other. In Thailand, the SPPs are allowed to build their own distribution system in industrial estate areas in order to reduce the burden of the national electricity generation. A similar case also happens in the telecommunication business in China as reported in [3].

Consequently, many wheeling charges methods have been introduced to solve this complex issue. The SPPs who cannot reach customers will have to make a contract with the DIOUs for wheeling the electricity through the DIOU networks. For example, some traditional wheeling charge methodologies are introduced in [1], the approaches based on the power flows tracing and sensitivity analysis are introduced in [4-7]. However, only some wheeling charge approaches are fair and equitable for every user. Moreover,

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the competition in wheeling charge model is still considered as an unfair competition as reported in [8].

The unfair advantage of the wheeling model is the private Distribution System Operator (DSO). When there is a private grid, it will always be followed by a private DSO who controls the power flows and generations in the grid. There is suspicion about the private DSO behavior. Normally, they would maximize benefit to their own customers in the wheeling business.

The purpose of this paper is, therefore, to introduce a conflict management model to solve the unbundling distribution system problem. The detail of the model will be illustrated in Section 2. However, before the decision can be made by the players (the network users) to agree with the proposed model, all players must first see the equilibrium on the benefit of the integration of the networks. This part can be explained by using non-cooperative game theory and the numerical examples in Section 3 and 4. All remaining topics will be discussed in Section 5.

2. Proposed Distribution Unbundling Model

With the current situation as described in Section 1, the entities in the distribution system can be illustrated in Fig.1.

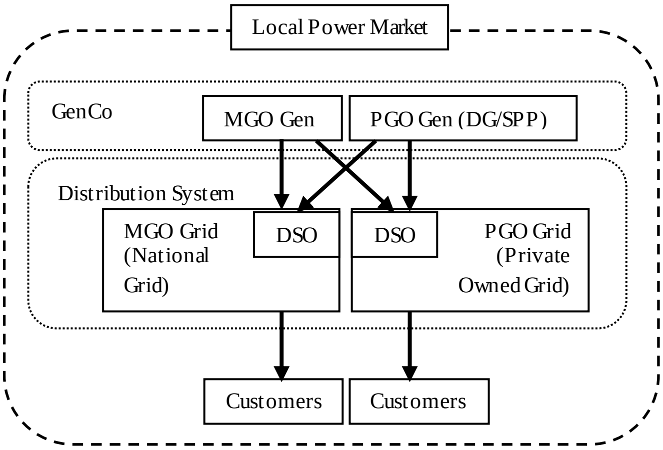


Fig. 1. Current situation in distribution system.

From the model in Fig.1, a local power market consists of 2 kind of distribution system grid companies. The first one is the main grid owner (MGO). This company is supposed to be the main authorized organization which is the monopolist in the market by laws. This kind of company does not exist in some countries such as The United States. The second one is the private grid owner (PGO) or the DIOUs who own both DG and networks. The network of both companies is disconnected. Each of them has their own customer in their network and are able to make a contract for wheeling the electricity to the outside customer too. The independent system operator (ISO) and PoolCo for marketplace are in between the generators and the GridCos. They still do not exist in some countries. In Thailand, there is still no marketplace, the MGO and PGO need to find their customers and dispatch their own generators themselves.

To achieve fair market competition, there is a need to integrate the distribution system together and unbundling the distribution system sector to be a single GridCo and single operator. The model can be illustrated in Fig. 2.

From Fig. 2, the network after integration will be unbundled and regulated by an independent entity called single GridCo. The entity will be operated by a fund called Distribution System Fund and sponsored by every network user who uses the system. The fund will be used for network maintenance and reinforcement to meet future demand.

Another entity that is also unbundled is the single distribution system operator (Single DSO). The operator is an entity which is able to monitor and control all activities for the whole integrated network. It could be formed as a single command center which controls every mini DSO in each private grid if suitable. This entity is responsible for the network administration and operation to control all DGs as also mentioned in [9]. For some countries that already have a marketplace, it could be also treated as an independent PoolCo.

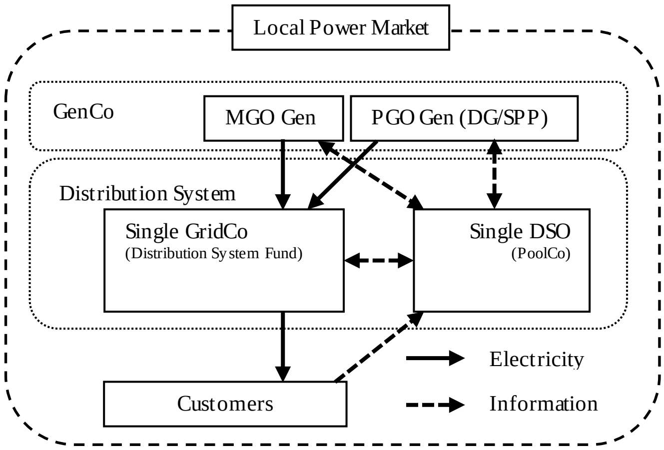


Fig. 2. Proposed distribution unbundling model.

Both fund and single operator must be independent from each other and independent from the network users. The fund members should consist of the members of every network user such as the representatives from MGO, PGO and even from the customers so that all decisions made by the fund will always have consensus. However, the fund manager must be independent and should not have any conflict of interest with the distribution systemor the network users.

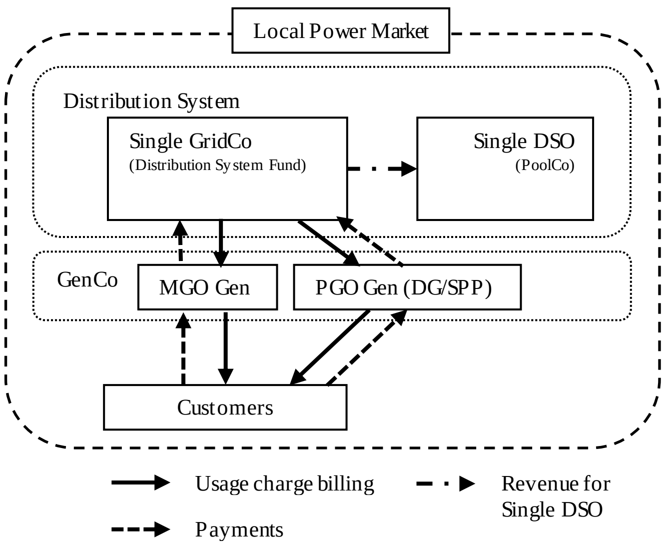


Fig. 3. Monetary flows for usage charges in the proposed distribution unbundling model.

The responsibility of each network user after integration is also a very important topic to be considered. The sustainability of the proposed model will depend on the cooperation of every network user. The network user must feel the responsibility is fair and equitable. After the networks are integrated and responsible by the single GridCo, the wheeling charge approaches can now be applied to obtain the network usage charges as every network user will be on a level playing field. Fig. 3 illustrates the monetary flows in the model. Without the single GridCo, the usage charge calculation will be complicate. It is not only to find an actual usage from each user, but a method to distribute all the payments to each grid owner is also required.

From Fig. 3, the usage charges will be calculated by GridCo. It will include all the cost recovery for network operation and maintenance, administrative cost, future investment and the revenue for the single DSO. The charges will be distributed to every network user i.e. the generators and the customers as their actual usage. The bill that is sent to each generator will consist of both the charges for the generator and their customers. The generators have to include the charges to each customer in their bill themselves. Once all payments have been collected, the GridCo will then pay the single DSO for its revenue.

The proposed model can solve the problem of over investment by centralizing the network operation, maintenance and future investment to GridCo. This model will also make the competition in the distribution system fairer. All players will be competing with each other in generation under the same rules from single DSO. The playing field is always open to any new players especially the small or very small power producer such as the roof-top photovoltaic, the small generation aggregators [10] or any other renewable energy generators.

However, the sustainability of the model depends heavily on the cooperation between the network users i.e. both generators and customers. Cooperation will not happen naturally because they are now both competitors and customers. To lead to cooperation, first of all, there is a need to inspire the network users and encourage them to start participating in the proposed model. Then, there is a need for usage charges calculation and distribution methodology that is transparent and always make the network users feel that they are charged in a fair and equitable manner.

3. Nash Equilibrium

Nash equilibrium is an approach to illustrate the equilibrium point of a non-cooperative game in the game theory when each player chooses a strategy that best responds to the strategies other players choose [11]. Neither player can do better by choosing some other strategies as long as the other player persists in the strategy that they have already chosen.

Non-cooperative game theory is a helpful tool that is frequently used to solve a conflict or find an equilibrium that benefits a situation such as in [12-14]. To inspire the network users to participate in the proposed model, there is a need to show them the benefits each user could obtain from the participation. In this section, non-cooperative game theory is applied to illustrate the choices of decision that a user can make and the consequence for each combination and the way to achieve Nash equilibrium.

3.1. Game setup

The proposed game is called Distribution System Game. It is assumed to have three vantage points which are the goals of each player. There is a need to find the equilibrium point which satisfies all players' objectives.

- Game Assumption

The game is designed to be played within the playing field. The field must consist of grid owner assets which must be allowed to become multi-ownership assets. Also, with the ability to physically join with each other. Using this definition, the playing field can be applied to any areas.

If the condition of an area does not meet the definition of a playing field, it cannot be treated as a playing field. For example, because of social equity reasons, an area of the national distribution grid where the sole owner must be a national authority organization cannot be treated as a playing field.

The decision making to join the network can be done by neglecting the technical impacts. The game will demonstrate the consequence of every possible decision. The technical impacts will be addressed later by the operators of the joint network.

The existing grid code will be temporarily neglected to remove any barriers for the new approach. A new grid code will be proposed later after the network has become a joint network already.

- Players

The game is designed to be played by 3 players i.e. the MGO, the PGO and the customers. Each player has it own objectives of the game as the following.

MGO: to take the ownership of the grid because it is still supposed to be a government company. However, they need to reduce cost of network construction and the burden to the national electricity generation.

PGO: to still be the owner of the grid because it is the assets that they have already invested in. However, they also need to reduce the cost of maintenance. Fair competition is also something they are concerned about.

Customers: in fact, they are not the competitors and do not own any grids, but their satisfaction can affect the strategies of the grid owners. The objectives of this player are to have a freedom to choose their own service provider. Also, to have a reliable network, to get a cheaper price for electricity or better services for the same price.

3.2. Algorithm

Objective: To maximize the benefit of the network users.

Algorithm: List all key processing indexes of all network users. List all possible scenarios based on the combination of the decisions from each user. Then, evaluate the key processing indexes in each scenario. The equilibrium scenario has the highest payoff function result. This process can be illustrated in Fig. 4.

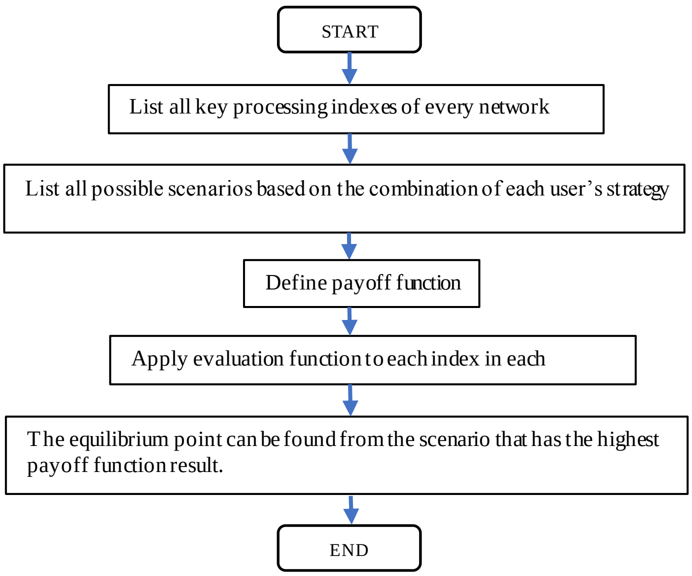


Fig. 4. Algorithm to obtain an equilibrium.

3.3. Network integration strategy

From the assumption, it can be written as a payoff function for network integration strategy as in (1)-(4).

$$F_W(w) = max\left(f_W^m(w_m), f_W^p(w_p), f_W^c(w_m, w_p)\right) \tag{1}$$

$$f_W^m(w_m) = NC_m \tag{2}$$

$$f_W^p(w_p) = NC_p \tag{3}$$

$$f_W^c\left(w_m, w_p\right) = \begin{cases} 1 & ; sastisfy \\ 0 & ; nuetral \\ -1 & ; unsastisfy \end{cases} \tag{4}$$

Where

$F_W(w)$ = payoff function for network integration

$f_W^m(w_m)$ = payoff function for network integration from the MGO's strategy

$f_W^p(w_p)$ = payoff function for network integration from the PGO's strategy

$f_W^c(w_m, w_p)$ = payoff function for network integration from the customers resulting from both the MGO and the PGO's strategy

w = combination of strategy from all network users

w_m = strategy of the MGO

w_p = strategy of the PGO

NC_m = maximum possible of customers of the MGO

NC_p = maximum possible of customers of the PGO

In this case, the key processing indexes for both grid owners are the number of possible customers that they could obtain. For the customers, it is their level of satisfaction from the strategy of both grid owners. The possible scenarios are when each grid owner decide whether or not to charge the other for wheeling. Table 1 illustrates the result of each payoff function and the equilibrium of the scenarios.

Table 1. Payoff between the two grid owners (the MGO and the PGO) under the network integration strategy

	PGO **$WC_p > 0$**	**PGO** **$WC_p = 0$**
MGO **$WC_m > 0$**	$F_W(C_m, C_p, -1)$	$F_W(C_m + C_p, <= C_p, 0)$
MGO **$WC_m = 0$**	$F_W(<= C_m, C_m + C_p, 0)$	$F_W(C_m + C_p, C_m + C_p, 1)$*

Where

WC_m = wheeling rate of the MGO

WC_p = wheeling rate of the PGO

C_m = number of customers in the MGO area

C_p = number of customers in the PGO area

* = equilibrium point

From Table 1, the result of the payoff function shows that the equilibrium scenario is when both grid owners do not charge each other for wheeling. The benefit that they could obtain is the maximum possible number of customers. This is open for fair competition between both grid owners. For the customers, they will be very satisfied with the strategy when both grid owners do not charge for wheeling. They can expect the freedom of choice to choose their own service provider.

3.4. Network participation strategy

After the networks are integrated into single GridCo, the network users still have a choice whether or not to participate in the network maintenance. This strategy can be written as a payoff function as in (5)-(11).

$$F_N(n) = max\left(f_N^m(n_m), f_N^p(n_p), f_N^c(n_c)\right) \tag{5}$$

$$f_N^m(n_m) = \sum_i f^m(k_i) \tag{6}$$

$$f^m(k_i) = \begin{cases} 2, & meet\ objective \\ 1, & get\ benefit \\ 0, & nuetral \\ -1, & not\ meet\ objective \end{cases} \tag{7}$$

$$f_N^p(n_p) = \sum_i f^p(k_i) \tag{8}$$

$$f^p(k_i) = \begin{cases} 2, & meet\ objective \\ 1, & get\ benefit \\ 0, & nuetral \\ -1, & not\ meet\ objective \end{cases} \tag{9}$$

$$f_N^c(n_c) = \sum_i f^c(k_i) \tag{10}$$

$$f^c(k_i) = \begin{cases} 2, & meet\ objective \\ 1, & get\ benefit \\ 0, & nuetral \\ -1, & not\ meet\ objective \end{cases} \tag{11}$$

Where

$F_N(n)$ = payoff function for network participation
$f_N^m(n_m)$ = payoff function for network participation from the MGO's strategy
$f_N^p(n_p)$ = payoff function for network participation from the PGO's strategy
$f_N^c(n_c)$ = payoff function for network participation from the customer's strategy
n = combination of strategy from all network users
n_m = strategy of the MGO
n_p = strategy of the PGO
n_c = strategy of customers
k_i = key processing index i
$f^m(k_i)$ = evaluation function against k_i for the MGO
$f^p(k_i)$ = evaluation function against k_i for the PGO
$f^c(k_i)$ = evaluation function against k_i for customer

In this case, the key processing indexes for every grid user are already listed in Table 2. The indexes can be of any topics that are concerned in the distribution system. In this paper, the indexes are taken from the objectives of each network user as described earlier to demonstrate the result of evaluation function. Table 3 illustrates all possible scenarios based on the combination of each user's strategy. The result of the payoff function against each scenario and the equilibrium are already illustrated in Table 4.

Table 2. The key processing indexes for every network user

Key	Description
K1	Claim the ownership of the network
K2	Has more reliable network
K3	Save operation & maintenance cost
K4	Reduce losses
K5	Defer the investment to the right time
K6	Fair competition

Table 3. Possible scenarios for network participation

Scenario	MGO	PGO	Customer
1	Participate	Participate	Participate
2	Participate	Participate	Not
3	Participate	Not	Participate
4	Not	Participate	Participate
5	Participate	Not	Not
6	Not	Participate	Not
7	Not	Not	Participate
8	Not	Not	Not

The evaluation function of each user will be checked against each key processing index whether the user can obtain the benefit and meet the objective or not. The function will return 2 scores when the benefit is obtained and meet the user's expectation. The benefit that is not expected before will get 1 score. When objective does not meet, the function will return -1. If it is neutral, then there is no score.

From Table 2, each chosen key processing index can be explained by the following.

K1: This is the objective of both the MGO and the PGO. They both need to claim an ownership on the network. When a player participates, they can claim the ownership as their participation.

K2: If there is a player participating in network maintenance, the network will be reliable. It is the main objective of both the MGO and the customers.

K3: Both the MGO and the PGO would like to save on network maintenance cost. Once the networks are integrated, the participation from customers should reduce the cost.

K4: This is the main objective of the MGO, the losses from the national grid must be reduced if the local grid can perform like a Micro Grid. This could happen from cooperation between the PGO and the customers.

K5: Future investment should be deferred until there is a signal from the network for reinforcement. When the networks are integrated and monitored by a single DSO, it will be possible. This is the objective of both the MGO and the PGO.

K6: Fair competition is the main objective of PGO. It can only be fair competition when every user or at least the MGO and the PGO comply to the same rules and participate in the network operation and maintenance.

Table 4. Sample how to obtain payoff value from each scenario when the players whether or not to participate in the network maintenance

Scenario	1			2			3			4			5			6			7			8		
KPI	M	P	C	M	P	C	M	P	C	M	P	C	M	P	C	M	P	C	M	P	C	M	P	C
K1	✓	✓		✓	✓		✓	✖		✖	✓		✓	✖		✖	✓		✖	✖		✖	✖	
K2	✓	O	✓	✓	O	✓	✓	O	✓	✓	O	✓	✓	O	✓	✓	O	✓	✓	O	✓	✖		✖
K3	✓	✓		✓	✓		✓	✓		✓	✓		✖	✓		✓	✖		✓	✓		✖	✖	
K4	✓			✖			✖			✓			✖			✖			✖			✖		
K5	✓	✓		✖	✖		✖	✖		✖	✖		✖	✖		✖	✖		✖	✖		✖	✖	
K6	O	✓		O	✓			✖			✖			✖			✖			✖			✖	
Total (F_N)	11	9	2*	5	6	2	4	0	2	4	3	2	1	0	2	1	0	2	1	0	2	-5	-4	-1

Where M = MGO payoff function $f_N^m(n_m)$ ✓ = get benefit, and meet objective – score = 2
P = PGO payoff function $f_N^p(n_p)$ O = get benefit – score = 1
C = Customer payoff function $f_N^c(n_c)$ ✖ = objective does not meet = score = -1

From Table 4, it can be noticed that the equilibrium is on Scenario 1 where the participation comes from every user.

From the result in Table 1, it can be noticed that the equilibrium cannot be reached naturally. The grid owner who starts adopting the strategy to not charge for wheeling first could have ended up as a loser if the competitor still keeps charging for wheeling. In a non-cooperative game, a player does not know each other's strategy so every player will be in defensive mode and choose the choice with least risk. That is why network integration never happens without a cooperation.

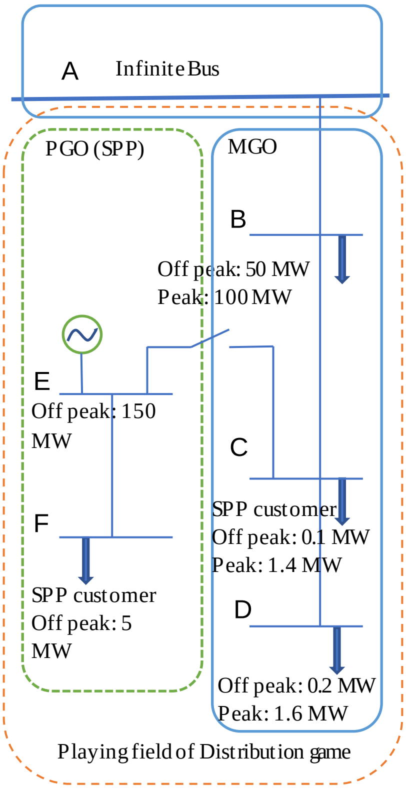
From the result in Table 4, it can be noticed that the more participation to the network, the higher the score returned from the payoff function. This means that every network user can obtain more benefits. The equilibrium point is the scenario where everybody participates and obtains their own optimal benefit.

4. Numerical Result and Discussions

Once the networks are merged together, wheeling charges can be applied to obtain the network usage charges. In Table 5, a numerical example on the tested distribution system is introduced with the result of power flow tracing methodology as in [4]. The distribution use-of-system (DUoS) rate of each distribution line is assumed to be the rate based on the defined costs of the line i.e. operation, maintenance, future investment, administration and miscellaneous cost. Therefore, each line will have different rates depending on its individual cost. The simulation is done for 2 periods i.e. the period when the network has maximum demand but minimum generation (peak period) and the period when the network has minimum demand but maximum generation (off-peak period). The total charges are the averaged usage charges from both periods.

From Table 5, it illustrates that all DUoS are charged to all network users based on their actual usages. During the peak period, the customers (demands) are the main users of the system. The MGO and the PGO generator does not need to pay for DUoS in this period. On the other hand, during the off-peak period, the excess power flows are the main network usage in the period. The PGO (SPP) generator has to pay 1,373,150 THB for its excess generation.

Table 5. Power flow tracing and DUoS charges in test system



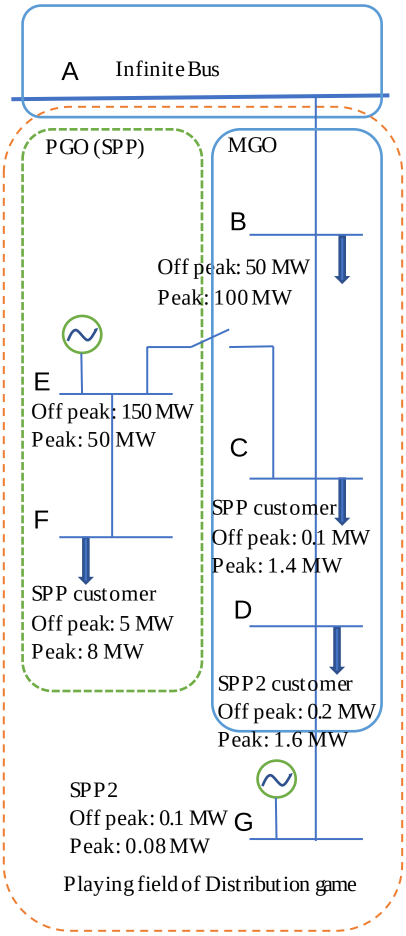
Network User / Node	Circuit	Peak Usages (MW)	Off-peak Usages (MW)	DUoS Charge Rate (THB/kW)	DUoS Charges for Average Usages ('000 THB)	Total DUoS Charges ('000 THB)
A (MGO) Gen	A-B	0	0	15.00	0.00	0.00
	B-C	0	0	6.00	0.00	
	C-E	0	0	8.00	0.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
B (MGO) Customer	A-B	61	0	15.00	457.50	1,080.50
	B-C	39	50	6.00	267.00	
	C-E	39	50	8.00	356.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
C (SPP) Customer	A-B	0	0	15.00	0.00	6.00
	B-C	0	0	6.00	0.00	
	C-E	1.4	0.1	8.00	6.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
D (MGO) Customer	A-B	0	0	15.00	0.00	12.60
	B-C	0	0	6.00	0.00	
	C-E	1.6	0.2	8.00	7.20	
	E-F	0	0	6.00	0.00	
	C-D	1.6	0.2	6.00	5.40	
E (SPP) Gen	A-B	0	94.7	15.00	473.50	1,373.15
	B-C	0	94.7	6.00	284.10	
	C-E	0	94.7	8.00	378.80	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
F (SPP) Customer	A-B	0	0	15.00	0.00	39.00
	B-C	0	0	6.00	0.00	
	C-E	0	0	8.00	0.00	
	E-F	8	5	6.00	39.00	
	C-D	0	0	6.00	0.00	
Total						**2,511.25**

The total DUoS 2,511,250 THB will be collected and posted into 2 accounts i.e. the future network reinforcement, operation and maintenance (O&M) account. The future reinforcement requirement can be guided by the rating of network usage. That can then be obtained from the power flows tracing result. The line that has a lot of usage and it already closes to its defined capacity will be considered at this stage. For the O&M, it can be allocated into 2 parts, one is the revenue for single DSO and the other is reserved as a fund to recover all operation and administration costs under combined system agreement.

From the simulation, it can also be noticed that the private networks of each grid owner no longer possess an unfair advantage for each grid owner. The competition in the distribution system is now back to the fair level. Table 6 illustrates a simulation when a new SPP with a roof-top photovoltaic generator and energy storage system (ESS) starts its business in the same distribution system as in Table 5. The result of the simulation in Table 6 shows that the customers at node B and D are charged less due to more usage on the lower cost lines. Meanwhile, SPP's generator is charged more due to more excess power generated on the off-peak period.

From both Table 5 and 6, it shows that, with the proposed model, it envisages a level playing field for the distribution system. Every network user has the responsibility or has to contribute to the distribution system through the DUoS charges which are based on the actual usage of each network user. The approach can guarantee that it will be fair and equitable for every user.

Table 6. Power flow tracing and DUoS charges in test system when there is a new SPP at node G



Network User / Node	**Circuit**	**Peak Usages (MW)**	**Off-peak Usages (MW)**	**DUoS Charge Rate (THB/kW)**	**DUoS Charges for Average Usages ('000 THB)**	**Total DUoS Charges ('000 THB)**
A (MGO)	A-B	0	0	15.00	0.00	0.00
Gen	B-C	0	0	6.00	0.00	
	C-E	0	0	8.00	0.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
	D-G	0	0	6.00	0.00	
B (MGO)	A-B	60.92	0	15.00	456.90	1,080.46
Customer	B-C	39.08	50	6.00	267.24	
	C-E	39.08	50	8.00	356.32	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
	D-G	0	0	6.00	0.00	
C (SPP)	A-B	0	0	15.00	0.00	6.00
Customer	B-C	0	0	6.00	0.00	
	C-E	1.4	0.1	8.00	6.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
	D-G	0	0	6.00	0.00	
D (SPP2)	A-B	0	0	15.00	0.00	11.88
Customer	B-C	0	0	6.00	0.00	
	C-E	1.52	0.1	8.00	6.48	
	E-F	0	0	6.00	0.00	
	C-D	1.52	0.1	6.00	4.86	
	D-G	0.08	0.1	6.00	0.54	
E (SPP)	A-B	0	94.8	15.00	711.00	1,374.60
Gen	B-C	0	94.8	6.00	284.40	
	C-E	0	94.8	8.00	379.20	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
	D-G	0		6.00		
F (SPP)	A-B	0	0	15.00	0.00	39.00
Customer	B-C	0	0	6.00	0.00	
	C-E	0	0	8.00	0.00	
	E-F	8	5	6.00	39.00	
	C-D	0	0	6.00	0.00	
	D-G	0	0	6.00	0.00	
G (SPP2)	A-B	0	0	15.00	0.00	0.00
Gen	B-C	0	0	6.00	0.00	
	C-E	0	0	8.00	0.00	
	E-F	0	0	6.00	0.00	
	C-D	0	0	6.00	0.00	
	D-G	0	0	6.00	0.00	
Total						**2,511.94**

Table 6 also illustrates that a new competitor can get into the electricity generation business without any problems and without being taken advantage of by the existing grid owners. The responsibility for the operation, maintenance and reinforcement of the grid has already been transferred to the independent entities i.e. single GridCo and single DSO. Therefore, it can be assured that grid owners cannot take advantage anymore.

5. Conclusions and Future Works

This paper has presented a model of distribution system operation that is able to solve the problem of grid owners breaching the natural monopoly asset. The model requires the unbundling of the distribution system to be a single GridCo and single DSO. With both entities, the competition in the distribution system will become fair competition in the generators. With this approach, the competition is open to any new competitors including small and very small renewable energy providers.

This paper also presents the equilibrium between all network users. The main suggestion is the networks of each grid owner i.e. the MGO and the PGOs should be integrated together and operated by an independent entity called GridCo. The second suggestion is every network user including the customers should participate in the network operation and maintenance by supporting GridCo. The contribution can be in the form of the usage charges that are calculated and distributed to each network user in a fair and equitable manner.

Once the networks are integrated, GridCo can simply adopt any wheeling charge approaches to calculate the network usage charges to every network user. The suggested approaches should be the approaches that are based on the power flows tracing. They can accurately identify how much power flows each user actually generates or uses.

The future investment cost is also important for the proposed model. The investment should be deferred to be at the right time to avoid over-investment. The cost should be bundled into the usage charges as well. However, how to calculate and distribute it to each user in a fair and equitable manner and a mechanism to defer the investment to be done at the right time is yet to be considered.

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