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GENERATION REVENUE ASSESSMENT ON RESTRUCTURING THE MALAYSIA ELECTRICITY SUPPLY INDUSTRY

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ABSTRACT

The Malaysia Electric Supply Industry (MESI) has been a regulated monopoly for many years. Tenaga Nasional Berhad (TNB) is vertically integrated from generation to distribution. Since 1992, Independent Power Producers (IPPs) and competitive bidding is introduced, which has opened for a level playing field in the generation sector, while others remained the same. Therefore, MESI had applied the single buyer model until today. In 2005, MESI has aimed to change its structure to a wholesale market model. Now, the single buyer model had passed several processes of evolution, but it still a form of imperfect competition because there is only one buyer and many sellers of a product. Thus, other alternatives of electricity market models have been proposed to carry on the MESI previous plan towards restructuring. This paper discusses three electricity market models; single buyer, pool, and hybrid market model. The case study is carried out to compare the three market models in term of generation revenue. Four busses of generator power plant have been chosen for the case study. Single buyer model shown an unfair trading. The generators can still generate revenue even without any contribution to supply the load demand and gained the largest revenue due to the existence of both capacity and energy payment. Furthermore, this market does not provide competition due to long term agreement. Thus, the results show that the single buyer is the most profitable for generation revenue compared to other market model due to capacity payment regardless the usage of real capacity based on the demand. Nevertheless, the pool and hybrid market model provide a fair trading as it based on energy bid price only.

Keywords: Malaysia electricity supply industry, single buyer, pool market, hybrid model.

INTRODUCTION

Generally, a privately owned vertically integrated utility carried out the supply electricity, whereas generation, transmission and distribution were owned and managed by the same utility over a certain area. Globally, the electricity supply industry (ESI) had undergone major transition. The significant multilevel playing field in the electricity supply industry is necessary to generate fair trading environment [1]. The implementation of competitive bidding in MESI is required in order to achieve generation revenue, to enhance efficiency, to create competition in order to lower costs and to increase customer choice. Therefore, the MESI reform transformation is clearly underway and more reform initiatives is expected and need to be implemented in the near future. There are several types of electricity trading arrangements applied in deregulated structure other than single buyer such as pool market, hybrid model and bilateral contract, which can create win-win situation to parties involved including consumers [2-6]. The MESI has been a regulated monopoly for many years, which TNB is vertically integrated from generation to distribution. Since 1992, the IPPs is introduced, and competition bidding is implemented, MESI had applied the single buyer model until today, which has opened for a level playing field in the generation sector, while others remained the same [7]. After had passed several processes of evolution, the single buyer model still a form of imperfect competition due to only one buyer and many sellers of a product. In 2005, MESI has aimed to change its structure to a wholesale market model [7]. Therefore, in order to carry on the MESI previous plan towards restructuring, other alternatives of electricity market model have been proposed. Three electricity market model; single buyer, pool, and hybrid market model were discussed. Then, the case study is carried out to compare in term of generation revenue. For the case study, four busses of generator power plant have been chosen, and the analysis of the power generation revenue has been done for three types of load demand which are at low load demand (1500 MW), medium demand (4000 MW) and high demand (5000 MW). Generation revenue for four generators in Malaysia are calculated. These four generators were used in order to acquire the results of generator's revenue for different types of market structure that are single buyer, pool market for uniform price as well as pay as bids and hybrid model for uniform price, pay as bids and system marginal price (SMP) payment. The calculations are based on four criteria's which are the available capacity for each generator in megawatt (MW), the capacity contribution range in MW, the capacity price in RM/kW/month and energy price in RM/MWh.

RESTRUCTURING EXPERIENCE IN ASEAN

Singapore market

Singapore's journey to liberalization started in October 1995, when the power system assets have been structured to facilitate commercialization and subsequent privatisation. The generation, transmission and

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distribution, wholesale and retails of electricity under Singapore Power (SP) after taken from the Public Utilities (PUB) [8]. The Singapore Electricity Pool (SEP), a day-ahead market, began the operation in 1998 [8]. A new legal and regulatory framework was introduced on 1st April 2001 as the SEP ended, which formed the basis for a new electricity market [9]. Under the electricity industry legislation enacted, Energy Market Authority (EMA) was established as industry regulator and Power System Operator (PSO); meanwhile, Energy Market Company (EMC) was established as the National Electricity Market of Singapore (NEMS) wholesale market operator.

The NEMS was formed and started trading in January 2003 [8]. The NEMS is designed to promote the efficient supply of competitively-priced electricity, open up the retail market to full competition, allow certain government-owned assets to be privatised, and encourage private investment in Singapore's power system infrastructure. The NEMS represents a progression from the pool to fully competitive wholesale and retail electricity markets [9].

Today, natural monopolies like the transmission grid have been separated from the competitive segments of generation and retail, while three of Singapore's largest commercial generators have been divested and privately owned by foreign investors. There are close to 30 market participants in the NEMS comprising commercial generators, embedded generators, wholesale market traders and retailers [9].

Thailand market

For many years, Thailand has faced challenges in restructuring its electricity supply industry. The Metropolitan Electricity Authority (MEA) was established since 1958, in order to provide electricity to customers in the metropolitan area with two others neighbouring provinces [10]. Meanwhile, in 1960, the Provincial Electricity Authority (PEA) was introduced in the remaining part of Thailand to provide electricity. By merging three regional utilities, in 1968 a state-owned enterprise, the Electricity Generating Authority of Thailand (EGAT) was formed, which owns from the generation to the distribution of electricity [11]. Following that, as the distribution companies, MEA and PEA has to buy the electricity from the EGAT. The IPPs has been introduced to participate and create competition in the generation level starting 1992 [12].

The electricity industry in Thailand has undergone privatization in stages, but the economic crisis in 1997 has accelerated the privatization activity to reduce the government debt, encourage competition and enhance private investments. The National Energy Policy Office (NEPO) has preside for ESI reformation study and came out with a restructuring model based on the pool, known as a price-base power-pool model, but it received strong objections because of the adequacy of the model such as price volatility and system reliability. It was revised, then, New Electricity Supply Arrangement (NESA) was proposed, but rejected by EGAT [13]. In 2002, due to the reorganization of all Thai bureaucratic system, NEPO changed its name to Energy Policy and Planning Office (EPPO). On 9 December 2003, Enhanced Single Buyer (ESB) was introduced as the new electricity market, where EGAT retains its monopoly on generation and transmission [10].

Indonesian market

The ESI of Indonesia was vertically-integrated, owned by national power company, Perusahaan Listrik Negara (PLN) [14]. In 1990, the IPPs was introduced. In 1992, to encourage participation from private sectors, electricity regulation was revised. Therefore, from 1990 until 1994, more than 25 contracts were approved by government, as a result, making Java-Bali area, the largest power system in Indonesia, which consumes and produces more than 80% of the total power in the country from shortage to overcapacity [13]. The purpose of the ESI restructuring is to establish a fully competitive electricity market. In 1994, the PLN was reform into corporate entity. A year later, Java-Bali assets were unbundled into two generation companies known as Indonesia Power and Power Java-Bali. In 1997, PLN faced with several financial difficulties, therefore, the ESI went for comprehensive reformation to improve the sector's performance, restore the financial viability, and ensure efficient power supply to customers.

In 1998, the government has introduced 'Power Sector restructuring' to change the government's role in the power sector through regulatory reform, industry restructuring, and private sector participation [15]. PLN has implementing single buyer model since year 2000. Power Purchase Agreement (PPA) has been signed between PLN and IPPs in order to buy the electricity generated by IPPs. In 2002, the government undertook measures to liberalize the nation's electricity by enacted a new law but the law has been declared unconstitutional by the Constitutional Court of Indonesia in December 2004, leaving the reform agenda abandoned.

ELECTRICITY MARKET MODEL

For many years, the electricity industry throughout the world has been vertically integrated. By 1990, many countries are encouraged to perform a huge transformation in the electricity supply industry towards deregulation. The purpose for restructuring is to introduce competitive competition, where the utilities are required to unbundle the retail services and form three separated groups, generation companies (GENCOs), transmission companies (TRANSCOs), and distribution companies (DISCOs). There are several factors affect the deregulation of the electricity industry such as politics, economics and regulatory needs [16].

The electricity trading arrangement available in deregulated structure such as single buyer market, pool market, bilateral contract, and hybrid/multilateral contract, which has its own distinct characteristic. Table 1

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summarized the characteristic of four types of electricity markets [13].

Table-1. Types of electricity market model.

Electricity market model	Descriptions
Single buyer model	(a) Preferred electricity market model as the first step towards restructuring the ESI (b) Single buyer market buy power from its own generator or the IPPs (c) IPP usually signed PPA with the purchasing agency (d) PPA includes two payments: •Energy payment to cater variation of demand •Capacity payment to cover the capital costs of the generators
Pool market	(a) Two main participants in pool model are producers or suppliers and customers or consumers (b) The pool operator, independent market operator (IMO) will attain the economic dispatch (c) Consists of two stages: • Unconstrained dispatch • Security constrained dispatched (d) The last generator being dispatched will determine the system marginal price (SMP)
Bilateral contract	(a) The two market participants are electricity buyer and seller (b) Allows electric power exchange such as MW amount, time of delivery, duration, and price (c) A buyer or seller has opportunity to choose the suppliers they want to negotiate with (d) No capacity payment involve in the market
Hybrid/Multilateral contract	(a) Combines the pool and bilateral model (b) Utilizing power exchange is not required (c) Allows customer to sign bilateral contract and choose supplier from the pool (d) Customers who choose not to sign bilateral contract will be served by the pool (e) It is a highly costs electricity market model

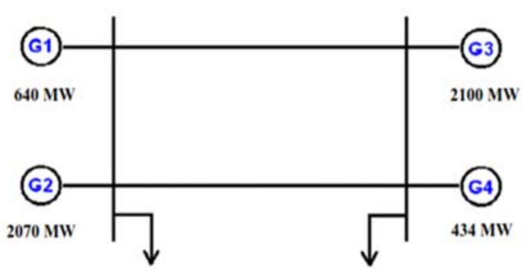

Figure-1. Four generators with two loads.

CASE STUDY

The case study is carried out by calculating the generation revenue for four generators around Malaysia. The analysis of the power generation revenue is done for three types of load demand which are at low load demand (1500 MW), medium demand (4000 MW) and high demand (5000 MW), in order to acquire the results of generator's revenue for different types of market structure that are single buyer, pool market for uniform price as well as pay as bids and hybrid model for uniform price, pay as bids and SMP payment. Four criteria are taken into accounts which are the available capacity for each generator in megawatt (MW), the capacity contribution range in MW, the capacity price in RM/kW/month and energy price in RM/MWh. Since, the monetary values involved in the study are confidential; therefore estimated values are being used instead.

A case study for four busses of generators power plant as shown in Figure-1 that supply three types of load demand is being used in this project. The purpose is to detail out the explanations towards the trading in three market structures model, in order to see the effect of load variation towards the generator's revenue. Figure-2 shows that the generation curve for the bidding process. The transmission network is assumed to be lossless. The available capacities in MW for each of these busses are being used to acquire all the results for generation revenue. From the results, a proper and depth analysis will be discussed and the conclusion will be made. Figure-3 shows the methodology flow diagram for the case study.

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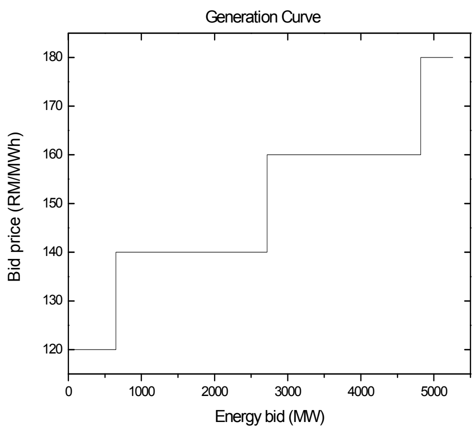

Figure-2. The generation curve.

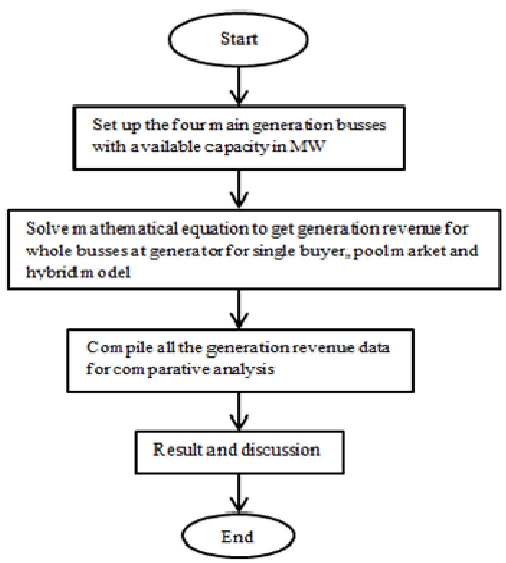

Figure-3. Methodology flow diagram.

Generation revenue for electricity market model

In single buyer model, each of private producers gain their revenue based on two types of payment rated in power purchased agreement (PPA) which are capacity payment and energy payment. The capacity payment (RM/kW/month) is to cover the capital and other fixed costs which are not covered by the energy price per kWh. Meanwhile, the energy payment is the price paid per unit of incremental output. Thus, the total generation revenue, G_T, for single buyer model, the mathematical equation is [2]:

$$G_T = \sum_{i=1}^{k} \left[\left(P_{Gi} \times C_{Gi} \right) + \left(P_{EGi} \times C_{Egi} \right) \right] \quad (1)$$

which P_{Gi} signifies power capacity available by ith generator in MW, C_{Gi} is capacity price for ith generator in RM/MWh, P_{EGi} is power output generated by ith generator in MW, C_{Egi} is energy price for ith generator in RM/MWh, and k is the numbers of generators involved.

In pool market model, there are two pricing scheme; uniform price and pay as bid. In uniform price scheme, all generators are being paid based on the pool purchase price, C_{PP} which effected by the system marginal price (SMP) regardless to their energy bid price. Therefore, the mathematical equations of total generation revenue, G_T, for pool market model with uniform price is [2]:

$$G_T = \sum_{i=1}^{k} \left(P_{Gi} \times C_{PP} \right) \quad (2)$$

which P_{Gi} signifies power capacity available by ith generator to the pool in MW, and C_{PP} is pool purchase price in RM/MWh.

Then, in pay as bid, the generators are being paid according to their energy bid price. Consequently, the mathematical equations of total generation revenue, G_T, for pool market model with pay as bids is [2]:

$$G_T = \sum_{i=1}^{k} \left(P_{GiPaB} \times C_{GiPaB} \right) \quad (3)$$

which P_{GiPaB} signifies power capacity available by ith generator to the pool in MW, and C_{GiPaB} is bid price for ith generation in RM/MWh.

A hybrid model is believed to be the most significant market model for MESI, because this model provide competition environment which guaranteed revenue for each generator regardless the types of demand and the generator's energy bid price, also able to reduce the effect of market power exercise as the traded electricity will be only held during the peak load. The hybrid model which combines the pure pool market and pro-rata base load consist of two properties that are base load demand and peak load demand. For base load demand, the base load sharing allows all generators to get their revenue regardless the current demand and their energy bid price. A pro-rata basis approach has been used to divide the base load fairly to all power producers. The portions of supply that obtain by each generator will proportional with their installed capacity, where the generators with higher installed capacity will participate more in supplying the base load demand. Thus, the mathematical equation that represents each generator's portion of supplying the base load demand can be written as [5]:

$$P_{GiBL} = \frac{P_{Gi}}{\sum_{i=1}^{k} P_{Gi}} \times P_{GTbl} \quad (4)$$

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which P_{GiBL} signifies generator share of base load demand, P_{Gi} is available capacity of a generator G_i, and P_{GTbl} is base load demand.

Meanwhile, for peak load demand, the remaining capacity from each generator is traded in the pure pool market model. As the remaining capacity for each generator is less, hence it is difficult for generators with higher installed capacity to monopoly the market. Moreover, the system marginal price can be reduced due to less remaining demand required for the pool market model. Listed below are mathematical equations of total generation revenue for hybrid market model:

a) Hybrid market with uniform price [4]

$$G_T = \sum_{i=1}^{k} (P_{GiBL} \times C_{GPaB}) + (P_{Gi} \times C_{PP}) \quad (5)$$

b) Hybrid market with pay as bid [4]

$$G_T = \sum_{i=1}^{k} (P_{GiBL} \times C_{GPaB}) + (P_{Gi} \times C_{GiPaB}) \quad (6)$$

c) Hybrid market with SMP [5]

$$G_T = \sum_{i=1}^{k} (P_{GiBL} \times C_{PP}) + (P_{Gi} \times C_{GiPaB}) \quad (7)$$

RESULT AND DISCUSSIONS

A case study of generation revenue for four generators that supply three types of load demand is discussed. The result in term of generation revenue will be compared under three market models; i) single buyer model; ii) pool model; and iii) hybrid model. From the results, clearly shown that the pool and hybrid market model provide a fair trading as it based on energy bid price only. Figure-4 shows the comparison between single buyer, pool market model for pay as bid and uniform price. It can be seen that the generation revenue for single buyer model are higher than the pool market model. The difference is significant especially at low load demand. For single buyer, the most expensive energy price rate, G4 is unable to sell any power during low and medium demand, but still gain the revenue because of capacity payment. Meanwhile, G1 the cheapest generator manages to obtain both payments at all types of demand, due to full capacity payment made to all IPPs without considering their actual capacity used by the demand. Instead of that, the generators also been paid for the energy payment. Although the total demand is low, with single buyer model, the generators will gain more profit.

For pool market model, only energy price rate will be considered. It is based on the competition among generators. Figure-4 shows that G4 unable to get any income for both low and medium demand. Due to energy price only, the expensive generator unable to obtain revenues at low demand whereas this generator only gets income during high demand. Generation revenue gain by generators for pool model uniform price is higher than pay as bid scheme, as shown at Figure-4, because for uniform price scheme, each succeeded generators will be paid based on the C_{PP}, which varies with the demand. Meanwhile, the payment in pay as bid is based on each generators bid price.

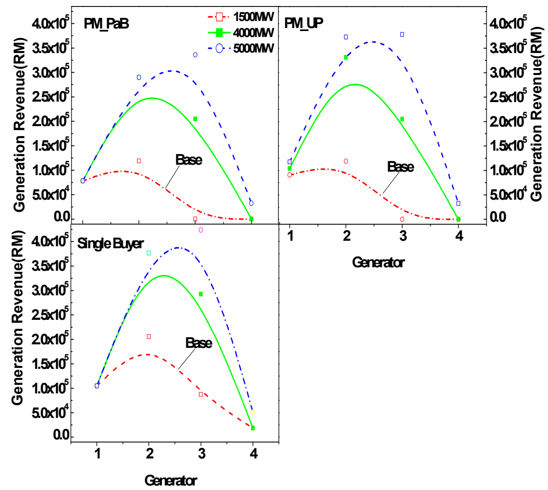

Figure-4. Generation revenue for pool market pay as bid (PM_PaB), pool market uniform price (PM_UP) and single buyer.

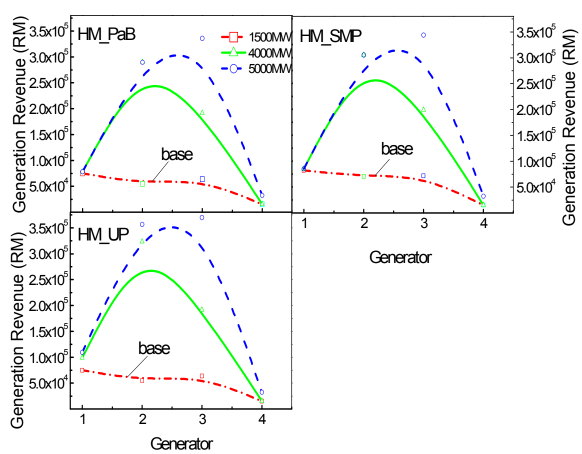

Figure-5. Generation revenue for hybrid model pay as bid (HM_PaB), hybrid model uniform price (HM_UP) and hybrid model SMP (HM_SMP).

For hybrid model, base load demand has solved the problem whereby the generators with expensive bid price could not gain any revenue during low demand. From Figure 5, during all types of demand, G1 to G4 still gain the revenue, because a part of their capacity has been used to supply the base load which can reduce their ability

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to conquer the market. Therefore, the effect of market power exercise will decrease, which tries to manipulate the system marginal price in pool trading. Hybrid model for uniform price and pay as bid scheme, base load payment referring to energy bid price, but for hybrid model with SMP payment, generator's payment for base load demand would be based on the SMP and the peak load would be based on their energy bid price. From the observation, result for both hybrid models, pay as bid and SMP payment are slightly same during all types of demand compared to hybrid model uniform price which is slightly higher because of peak load is pay based on C_{PP} which are varies from time to time. Therefore, during peak load, hybrid model uniform price will gain more profit.

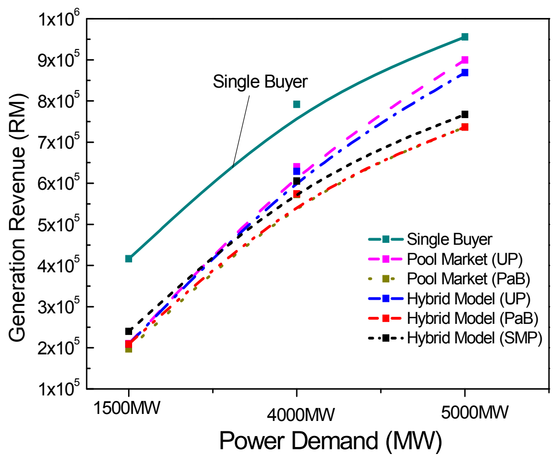

Figure-6. Total generation revenue for single buyer, pool market and hybrid model.

Figure-6 shows total generation revenue for single buyer model, pool model with uniform price and pay as bid, hybrid model with uniform price, pay as bid and SMP payment. During low demand, the generation revenue is not much differing for all models except single buyer model. The differences can be seen clearly starts from medium to high load demand. This is because various type of payment involved for energy produced whether using C_{PP} or energy bid price. Single buyer is the most profitable for generation revenue compared to other market model due to capacity payment regardless the usage of real capacity based on the demand. This situation will only benefit to the power producers only. Generation revenue for hybrid and pool model under pay as bid scheme is almost the same, but slightly higher for hybrid model with SMP payment because the base load payment is based on SMP. For hybrid and pool model with uniform price, the generation revenue nearly similar during low to medium load demand. While up to high demand, pool model with uniform price is slightly higher compared to hybrid model with uniform price. This is because energy produced for hybrid model with uniform price, is paid according to energy bid for baseload demand and C_{PP} for peak load demand. Therefore, the peak load demand as the remaining capacity available for each generator is less, it is difficult for big generators to monopoly the market and the system marginal price which affect the C_{PP} can be reduced due to less remaining demand required for the pool market model.

CONCLUSIONS

Under the single buyer model, the generators had gained the largest revenue due to the existence of both capacity and energy payment. These generators still can obtain revenue even without any contribution to supply the load demand. This market model does not provide any competition due to the long-term agreement; that simplify the electricity trading under one company which is TNB transmission and distribution. The pool market model on the other hand, offers full competitive model, based on energy price only and fully removed the capacity payment and therefore reduces the revenue some of the generators quite significantly. The most expensive generators might not be able to get any revenue at all. Hence, will force each of them to bid for the cheapest energy price most of the time and this will create competition. Consequently, MESI need to change the current market model used as it affect to various level of parties involved. It is suggested the hybrid market model is the best to replace the single buyer model. Hybrid model seems to be very effective as it gives the opportunity to all generators to participate not only in base load demand but also in peak load demand. Therefore, the implementation of hybrid model, the revenue of IPPs is reduced due to changes. However, all IPPs have equal opportunities to get exceptionally high revenue when demand exceeds availability supply and power suppliers up to their bidding prices to take advantage of the situation. Finally, the generators will get reasonable profit, the distributor company will be able to pay appropriate amount and end-consumers will enjoy a low electricity tariff.

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