ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

Navigating Towards a Sustainable Electricity Supply in Indonesia

Ly Fie Sugianto[1]

[1] Faculty of Business and Economics, Monash University, Victoria, Australia

Correspondence: Ly Fie Sugianto, Faculty of Business and Economics, Monash University, Caulfield East, Victoria 3124, Australia. Tel: 61-3-9903-2813. E-mail: Lyfie.sugianto@monash.edu

Received: July 27, 2014 Accepted: August 10, 2014 Online Published: September 1, 2014

doi:10.5539/mas.v8n6p14 URL: http://dx.doi.org/10.5539/mas.v8n6p14

The research is financed by the Australian Indonesian Governance Research Partnership (AIGRP)

Abstract

The realization that natural resources are limited has triggered a global sustainability movement, including in the electricity sector. Sustainable electricity supply is within the national agenda of many countries given that the demand for electricity has shown a consistent increase over many decades. An important aspect of sustainable electricity supply is the pricing of electricity. The objective of this study is to explore the effectiveness of a competitive electricity market structure in the Indonesian case. While restructuring, deregulation and privatization in the electricity industry is aimed at improving efficiency in electricity supply and ensuring competitive electricity price, experiences from other countries indicate that competitive market can lead to high price volatility and gaming behavior among market players, leading to more expensive electricity price. This study proposes to use an agent based model to simulate a competitive market. The focus of the study has been on the installed generation capacity in the region to ensure availability of supply and competitive pricing. The study features the Java-Bali grid and uses the half-hourly demand data from the region to observe the pricing dynamics.

Keywords: computer simulation, deregulation, electricity market, spot price

1. Introduction

The traditional model of the electricity industry sector is monopolistic, mainly because the state owns and governs the generation, transmission and distribution of electricity through its company. With this structure, generation companies receive stable revenues from the government. Generation companies are not motivated to seek for alternative technology to improve efficiency in generation, because there is a lack of incentive for technology innovation. Power outages that often occur with this model indicate that system reliability is also an issue. In generation, the quick fix for this problem is by increasing the number of stand-by power plants. To fulfill the growing demand of electricity, the state-owned company plans new investments in generation and transmission networks on the basis of break-even schemes. Often, this results in over investment.

To cope with the high cost associated with electricity generation, transmission and distribution, the government provides substantial subsidy so that consumers can afford electricity to facilitate their lifestyle. Evidently, there is a lack of mechanism to transfer the high costs of supply to electricity consumers; and as a result, this structure discourages demand side participation. Instead of using the electricity wisely, consumers tend to use air conditioning systems excessively during hot days.

By contrast, in a competitive market structure, individual generators as market participants are free to make profits and are responsible for their own decisions. Thus, they are motivated to improve their efficiency in order to increase their profit margins. The decentralized decision making in a free, competitive market promotes efficiency in the production, transmission and distribution of electrical energy. Efficiency in the market is also achieved when market participants receive the right market signals and respond rationally and economically to these signals. For example, a shortage of electricity usually leads to high spot prices. These high prices in the short term encourage consumers to reduce their consumption, and in the long term invite prospective companies to enter the market by investing in new generating plants.

The past decade has seen a reformation in electricity industries around the globe. Restructuring, deregulation and privatization in the electricity industry is aimed at improving efficiency in generation, transmission and consumption of electrical energy, to attract investments in the markets, as well as to ensure competitive electricity price. Countries that have implemented such reform include England and Wales, Nordic countries, Germany, USA, Australia, New Zealand, Singapore, and India. Experiences from some of these countries indicate that competition in electricity markets can lead to high volatility in spot price and gaming behavior among market players, leading to more expensive electricity price.

1.1 Experiences from Competitive Electricity Markets Around the World

The international experience on privatization has not been universally positive. While in some markets, deregulation and privatization do not deliver economic benefits, in other markets, the industry reform results in lower price and reliable supply. Undoubtedly, it is our interest to compare the difference in electricity prices resulting from these markets. Table 1 lists the comparison of the average national electricity prices in various markets around the world.

As can be seen from Table 1, in most countries the electricity price tends to increase, except for in Croatia, Iceland and Italy. Household consumers in Denmark pay 41 cents per kWh for electricity, the highest electricity price in the world, because of the tax and energy policy strategy announced by the Danish government in 2011. Electricity is also costly for household consumers in other Nordic countries (Sweden and Finland), Europe (Germany, Belgium, Netherlands, Ireland, Italy and UK) and Australia.

Deregulation experience of the electricity industry in the USA is quite discouraging. Deregulation has been incomplete with most states still require generators to get permission from the government to raise prices. Continued regulation still led to unavailability and extreme price fluctuation in several states. In California, deregulation has led to a disaster, mainly because the market was more re-regulated than deregulated. Retail price regulation with producers' subsidy led to excessive consumers and inevitable supply shortages (Ritschel and Smestad, 2003). A study by the Government Accountability Office (Wells, 2005) stated that the restructuring effects on consumers have been mixed. The study also reported that the result of the wholesale market competition had been difficult to measure, because other factors, such as lower raw energy prices may have contributed to the decrease in the electricity price. On the positive side, in some states with substantially deregulated markets, consumers have benefited from significant savings following the use of smart metering and innovative residential pricing plans (Barnett and Shurtleff, 2007).

In UK, there were two major issues that arose following the privatization of electricity industry. Firstly, the Unions accused the Thatcher government to have sold the industry too cheaply. There was a criticism over inadequate accounting systems which make it difficult to estimate the value of businesses. Secondly, there was a fall in the number of employees, with a high number of redundancies. The later issue was debatable because of the common nature of excessive manning in a state-owned industry. On the positive side, there have been considerable impacts on national debt and public sector borrowing, as well as increased efficiency and productivity. Electricity reform in the UK can be considered a success judging from the supply reliability and low prices to small consumers (Newbery and Pollitt, 1997). Moreover, there was a major shift from coal to natural gas. UK is currently the world leader for installed offshore wind power, with a 589 megawatt capacity of eight operating offshore wind farms and seven more under construction (Central News Agency, 2008).

In Australia, the deregulation experience has been both positive and negative. Effective design of the energy market in terms of competition, and efficient design of ancillary services have been reported by Outhred (2000), Thorncraft and Outhred (2007). The observation reported in the Auditor-General's Report (Achterstraat, 2008) for the NSW region was quite positive. However, there have been incidents that the electricity price reached its cap in various regions with no logical explanation (Wilson, 2007). In general, the electricity price in Australia has increased in the past few years due to the weather conditions and drought to impact on electricity supplies.

Table 1. Electricity tariff comparison

Country/Territory	US cents per kWh		Changes
	2006-2007[a to e]	2011[f to i]	
Australia	7.11	29	$21.89 increase
Belgium	11.43	29.08	$17.65 increase
Canada	6.18	10	$3.82 increase
Croatia	17.55	12.6	$4.95 *decrease*
Denmark	22.89	41	$18.11 increase
Finland	6.95	20.65	$13.7 increase
France	8.54	19	$10.46 increase
Germany	13.16	35	$21.84 increase
Hong Kong (Kowloon)	10.90	12.13	$1.23 increase
Iceland	11.61	10	$1.61 *decrease*
Ireland	23.89	28.36	$4.47 increase
Italy	36.74	28	$8.74 *decrease*
Netherlands	12.62	28.89	$16.27 increase
Spain	10.35	21	$10.65 increase
South Africa	3.56	10	$6.44 increase
Sweden	6.60	27.1	$20.5 increase
UK	11.16	20	$8.84 increase
USA	9.28	12	$2.72 increase

Sources:

[a] http://pepei.pennet.com; [b]http://www.hep.hr/ods/en/customers/tariff.aspx

[c]http://www.or.is, [d]http://www.cplponline.com; [e]http://www.esb.ie

[f] http://cleantechnica.com/2013/09/30/average-electricity-prices-around-world/

[g] http://en.wikipedia.org/wiki/Electricity_pricing, [h]http://epp.eurostat.ec.europa.eu

[i] http://www.legco.gov.hk/yr10-11/chinese/panels/edev/papers/edev1214cb1-700-4-ec.pdf

1.2 Challenges in the Indonesian Electricity Industry

In Indonesia, increase in electricity demand has been quite rapid due to the growing industrialization. As can be seen in Figure 1 and detailed in Table 2, the demand of electricity in Indonesia has shown a consistent increase in the past decade. The rather low electrification ratio indicates the under-supply of electricity in Indonesia.

The State Electricity Utility Company or Perusahaan Listrik Negara (PLN) has diversified assets located across Indonesia. Given that sixty percent of the population (about 140 million people) resides in Java, the Java-Bali region represents eighty percent of the energy demand requirement in Indonesia. The demand is fulfilled by approximately three-quarters of the total generating capacities within the Java-Bali region. In 2008, the Indonesian government (through PLN) has developed a ten-year plan to install additional capacities for electricity generation in the region (see Figure 2). Apart from meeting rapidly increasing electricity demand in the Java-Bali region, PLN is also under immense pressure to increase the electrification ratio and ensure the reliability of electricity supply across the Indonesian archipelago. The following section provides an overview of the main challenges faced by PLN, in particular on how the unresolved institutional settings have complicated efforts in restructuring the electricity sector in Indonesia.

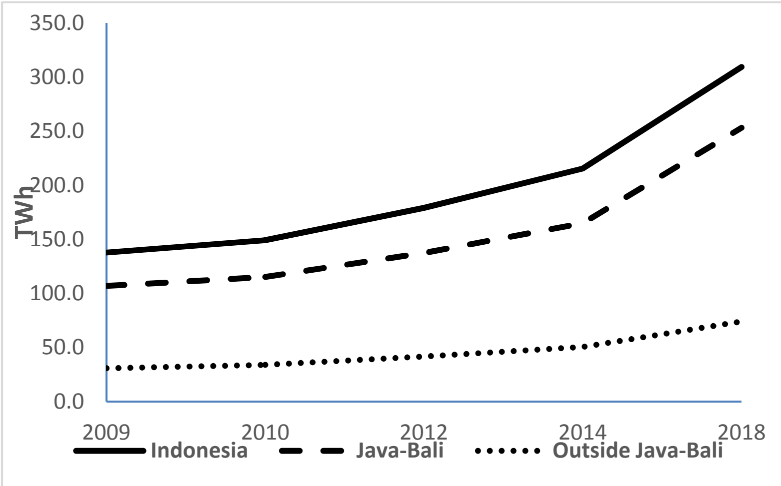

Figure 1. The past and projected energy demand graph

Source: http://energy-indonesia.com/03dge/0120918-01.pdf.

Table 2. The past and projected energy demand in indonesia

	2009	2010	2012	2014	2018
Energy Demand (in TWh)					
Indonesia	137.9	149.3	179.2	215.6	309.4
Java-Bali	107.0	115.3	137.5	165.0	253.3
Outside Java-Bali	30.9	34.0	41.7	50.6	74.1
Electrification Ratio					
Indonesia	66.9%	69.3%	75.0%	81.2%	92.6%
Java-Bali	70.0%	72.6%	78.7%	85.4%	97.9%
Outside Java-Bali	61.3%	63.2%	68.3%	73.6%	86.1%

Source: http://energy-indonesia.com/03dge/0120918-01.pdf.

Prior to 1997, PLN received subsidized oil fuels for its operation from the government since Indonesia was a net oil exporter. However, during the 1998 financial crisis, the utility company was unable to meet its financial obligations to independent power producers, and must receive financial support from the government. From 2002 to 2004, the government implemented a targeted subsidy scheme to low-voltage level services (up to 450 VA). PLN was compensated for costs of supplying electricity at the subsidized tariff. Starting in 2005, the state utility company PLN had been given a role by the government to Public Service Obligation (PSO). Its focus was to provide electricity to all customer categories (domestic, industrial, social, business, and public) with tariff set by the government. These sale prices were lower than the unit production costs, thus the government had to subsidize the difference. However, an increase price of oil fuel rapidly drained the state budget in subsidizing the electricity prices. Figure 3 displays the trend in government subsidy over the past decade.

Operating with limited funds, PLN faced a major impediment in building new generators to keep up with the growth of electricity consumption. Many planned generation projects had to be suspended during the financial crisis. Subsequently, there were frequent power blackouts occurring in many regions including Java and Bali. As a single integrated company, PLN has a huge responsibility in providing adequate and reliable electricity supply to millions of customer. The biggest issue has been the fact that the heavily subsidized electricity price created distortion in the use of electricity and inefficiencies. The growth of electricity consumption may not reflect the real electricity demand for the following two reasons: heavily subsidized electricity price and a low electrification rate.

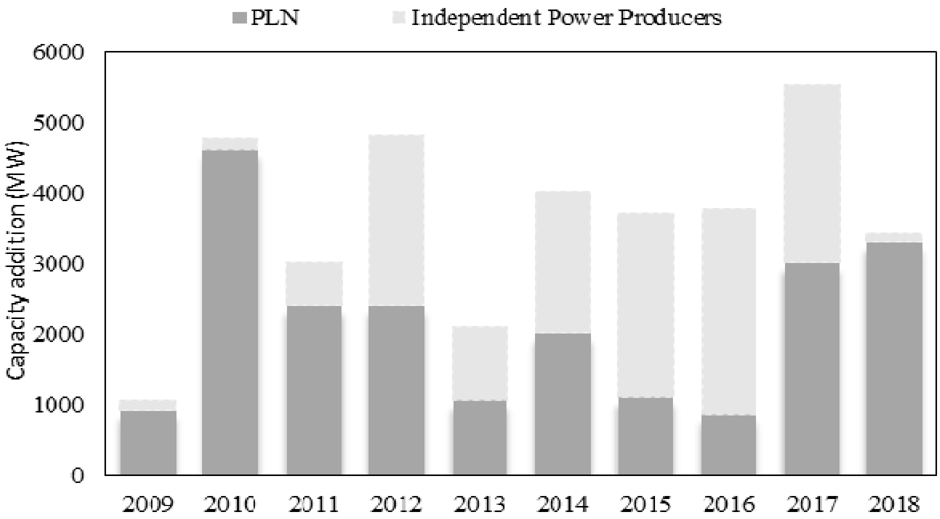

Figure 2. The Java-Bali development plan

Source: www.pln.co.id.

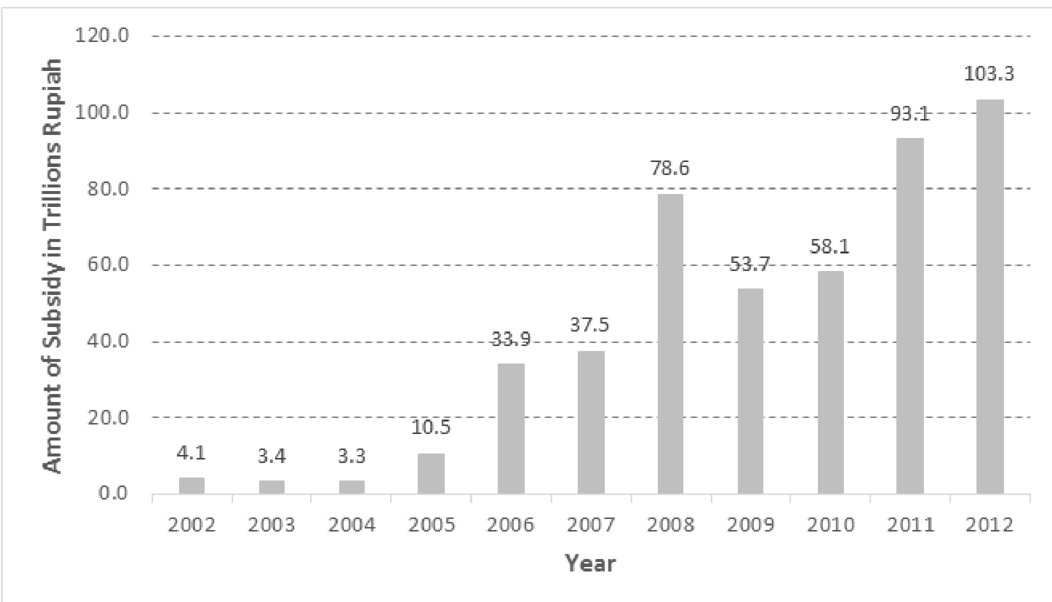

Figure 3. The Trend in Subsidy/PSO amount

Source: www.pln.co.id.

Although there seems to be path towards restructuring the industry, the process has been quite stagnant with some institutional changes outlined as follows. The Indonesian electricity law no.20 year 2002 introduced full competition in electricity industry in Indonesia within five years. However, the Constitutional Court annulled this law in 2004 because the substance of this law was deemed not in line with article 33 paragraph 2 of the 1945 Constitution. The Constitutional Court did not reject the idea of introducing competition in the electricity industry as long as control still rested on the state. Still, the electricity sector was in an uncertain state for a number of years. There was an announcement on the introduction of a new electricity law in 2009. Yet, the Indonesian electricity law no.30 year 2009 that legislated to end PLN's monopoly in the electricity sector remained controversial. As such, the electricity sector continues to remain in somewhat uncertain situation.

To date, the Indonesian electricity industry can be characterized as a partial deregulation with the state, through the state-owned company PLN, still manages the bulk of the electricity supply and controls the pricing and the tariff structure for domestic and foreign private companies that sell and supply electricity to consumers using PLN's transmission network infrastructure. A single buyer market has been adopted to adhere to the decision of the Constitutional Court on the judicial review of electricity law no. 20/2002 and/or law no.30/2009. In a single buyer market, only the supply side is open for competition. Competition on the supply side will give benefits to more efficient generation plants, and naturally will phase out inefficient plants. Consequently, the unit production cost is expected to be lower. An increasing average market price signals the need for more electricity supplies and attracts market participants to build new plants. Likewise, high spot prices will attract new players to invest in new generation and/or transmission network.

In summary, the Indonesian electricity sector remains as a predominantly single buyer model until all parties are ready for movement towards industry reform. The way to move forward has been incremental, namely by improving incentive in the sector and reducing the generation cost progressively.

1.3 Characteristics of Load Demand and System Generation in the Java-Bali Grid

Given that the Java-Bali system is the largest interconnected power system in Indonesia, it is chosen as the focus of this study. The system consists of four regions, namely Jakarta-Banten, West Java, Central Java-DIY and East Java-Bali. High load demand is frequently observed in the western area while surplus generation is in the eastern area. Consequently, there is a frequent flow of electricity from East to West. The commission of the Southern 500 kV extra-high voltage transmission line has significantly improved the stability of the system and removed transmission congestion.

In 2007, the generation composition consisted of thermal plants with net generation capacity (NGC) 9,736 MW, combined cycle gas turbine plants with NGC 6,466 MW, open cycle gas turbine plants with NGC 731 MW, hydro plants with NGC 2,477 MW, and geo-thermal plants with NGC 899 MW. A complete dependency of OCGT on oil fuel was due to unavailability of pipeline connection to gas supplies or Liquefied Natural Gas terminals near the plant site.

Table 3 shows the composition of generators in Java-Bali categorized by their designed operation modes: base-load, intermediate and peaking. Both thermal and geo-thermal plants are designed to run at high capacity factor and serve base-load duties. Combined cycle gas turbine (CCGT) plants serve intermediate load duties while open cycle gas turbine (OCGT) plants typically serve peak load duties. Since all of the existing hydro power plants are dam-type and do not have plenty of water supply, they typically have a low average of capacity factor (26.7%) and mainly serve peak load duties. So, the net generation capacities for base-load, intermediate, and peaking plants are 10,635MW, 6,466MW, and 3,208MW respectively.

Table 3. Composition of generators in the Java-Bali system

Plant Type	Hydro	Thermal	CCGT	OCGT/Diesel	Geo-thermal	Total
Net Generation Capacity (MW)	2,477	9,736	6,446	731	899	20,309
Capacity Factor (%)	26.7%	75.7%	45.8%	34.5%	91.7%	

1.4 Research Objective

This study aims to investigate the effectiveness of introducing a competitive electricity market in Indonesia. For this purpose, the study employs an agent based simulation approach to observe the pricing behavior and market performance. Currently, there are two dominant players in the Java-Bali grid, namely: meeting roughly 60% of the demand in the grid with 9000 MW capacity and 6500 MW capacity. Multi-agents can be used to represent independent power producers (IPP) in a minor restructuring scenario. Alternatively, when simulating major restructuring scenario, agents can be used to model different generation companies (as entities) with their own bidding behaviour in an oligopoly context.

The remaining of the paper is organized as follows. Section 2 outlines the electricity market operation and provides a literature review on the use of the agent-based model in studying the competitive electricity market. Section 3 introduces the agent based model employed in the study. Section 4 reports the simulation results. Section 5 provides the concluding remarks that summarize the key findings in the study and proposes some avenues that can be adopted as a pathway towards sustainable electricity supply in Indonesia.

2. Agent-Based Approach in Studying Competitive Electricity Market

2.1 Market Operation

The conceptual model of a competitive electricity market involves trading electricity via a central pool. An independent system operator (ISO) governs the market by announcing electricity demand for at a particular trading interval, receiving bids from generators and resolving the auction.

Generators bid their supplies and receive payment for the amount of energy they supply to the pool, while buyers pay for the amount of energy they purchase from the pool. This central (or spot) pool is a logical model to facilitate the financial aspect and the economics of scheduling, pricing and dispatch. In real life, generation companies supply electricity onto the transmission networks; and the distribution companies set various tariff structures and use metering systems when supplying electricity to consumers.

The independent system operator employs a centrally coordinated dispatch process to manage the operation of the pool. Generators offer daily bids distributed in ten quantity-price bands. Each bid consists of amount of energy to be dispatch at specific asking price. Customers submit demand bids, detailing the price and demand they wish to be scheduled, to ISO as the central dispatch coordinator. The central coordinator schedules the generation and demand for dispatch with the objective of minimising the cost of meeting electricity demand based on the quantity-price bid pairs. There are a fixed number of trading intervals in a day. Spot prices are influenced by many factors, such as the dynamics of supply and demand, generation availability, inter-regional/intra-regional transfer constraints and losses and excess generation. The repeating auction process in the electricity market is the mechanism to discover an equilibrium price (as an acceptable price) based on the demand, supply capacity and the current market conditions.

2.2 Literature Review

The agent based simulation model has recently emerged to be the popular approach for electricity market modeling in recent decades. This is mainly because electricity market modelling is complex due to the inherent, non-linear nature of the electricity generation-transmission-distribution process, as well as the market (trading) operation. A new paradigm for studying complex systems offers a different perspective that focuses on describing relationships among entities (or agents) in the system and observing the emergence that occurs as a result of the interdependent interaction among the entities. This paradigm allows dynamicity in the system and researchers observe the evolving behaviour of agents over time. In the electricity market model, generators are the agents under study. Other agents, such as the independent system operator, may be required to complete the market model, but not the focus of the study.

Entriken and Wan (2005) developed and used computer-based agents to simulate the impact of the California ISO and proposed automatic mitigation procedure for limiting the exercise of market power. Koesrindartoto, Sun and Tesfatsion (2005) tested the reliability of the economic reliability of wholesale power market using an agent-based computational economics model. Bagnall and Smith (2005) used an agent-based computational economics approach for studying the effect of alternative structures and mechanisms on behaviour in a simulated model of the new electricity trading arrangements in England and Wales electricity market. Papageorgiou (2004) developed an agent-based computational model to investigate the bidding behavior of generating companies in a short-term bilateral market. Bunn and Oliveira (2003) designed a multi-agent evolutionary model of the proposed new electricity trading arrangements in the United Kingdom for assessing market power abuse. Sponsored by the Electric Power Research Institute (EPRI), Amin (2002) designed and developed the Simulator for Electrical Power Industry Agents (SEPIA). SEPIA used autonomous adaptive agents to represent possible industrial components, such as generation units, transmission system, load, and the corporate entities, in the market model.

In recent years, there have been many researches focusing on the design of bidding strategies for the intelligent agents. Artificial intelligence can be embedded in generator agents to make them autonomous and adaptive. Popular AI techniques such as Neural Network, Genetic Algorithm, Game Theory and Reinforcement Learning can be implemented as agents' mechanism to bid strategically. Veselka et al. (2002) defined the agents' learning strategy based on Genetic Algorithm. Sheble and Gutierrez-Alcaraz (2012) used Genetic Algorithm to implement agents' adaptive bidding strategies. Learning strategy is crucial for agents to maximize their profit and reinforcement learning algorithm (Erev and Roth, 1998; Sutton and Barto, 1998) seems to be the most popular choice for designing agents' bidding strategies. Applications of reinforcement learning algorithms for agents' bidding strategies have been reported by Sun and Tesfatsion (2007), Tellidou and Bakirtzis (2007), Gallego, Duarte and Delgadillo (2008), Huang and Liu (2009) and Sugianto and Liao (2014).

3. The Agent-Based Model

This study employs an agent based model to observe the pricing dynamics in an auction market context. Because of the complexity in the electricity market model, market players/participants can benefit from simulation tools to help them understand the market behavior. An agent based market simulator can capture the dynamicity of the market, including those caused by strategic behavior of bidders. The simulation model is useful for providing inter-temporal information about how the market behaves. It is also useful to determine optimal trading arrangement yielding low cost and high availability level.

In this study, a virtual competitive environment is created by simulating a market that composes of several generating companies (gencos), as shown in Figure 4. The gencos in the region are represented by intelligent agents. Each agent has a portfolio of plants characteristics, such as type of plant, maximum capacity, fuel type, and costs. For each trading period, the agent submits a ten increasing band of quantity-price bid. Each bid reflects all available capacity, taking into account the ramp rate of the power plant whenever relevant.

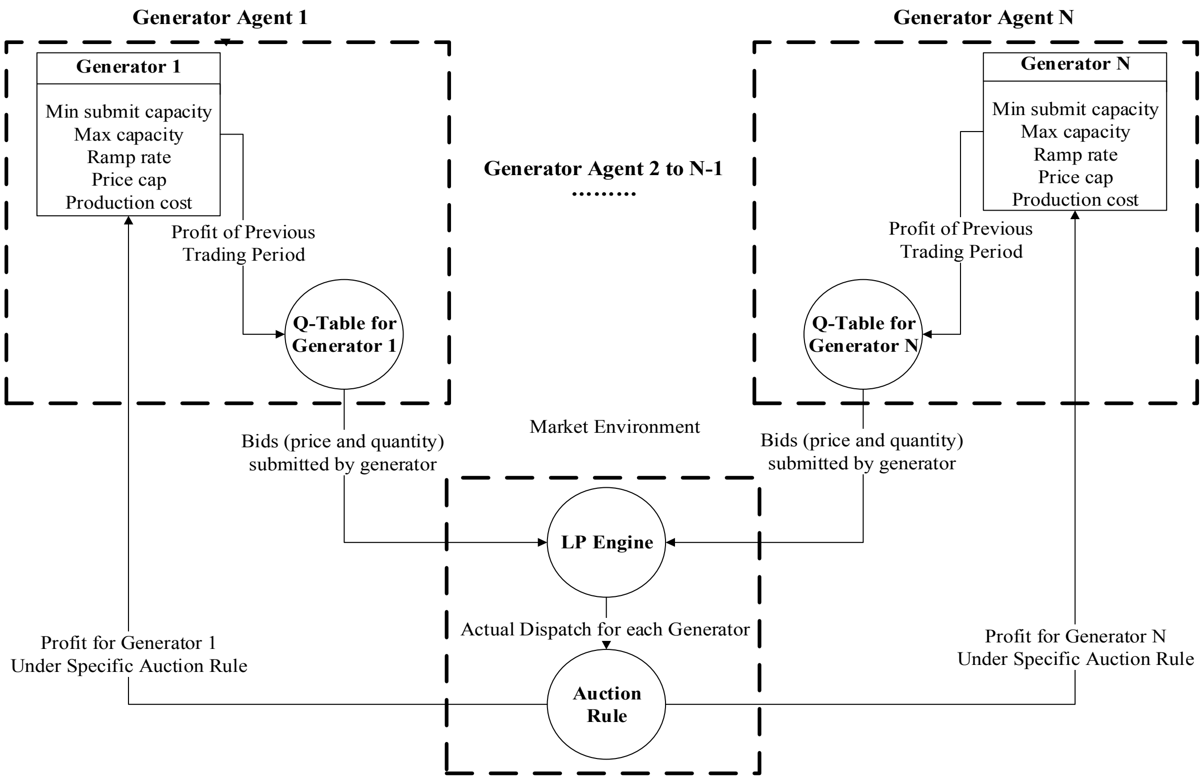

Figure 4. The agent-based simulation model

The agent-based model developed in this study extended our previous model (Sugianto and Liao, 2014) as follows:

- The central dispatch coordinator agent has been programmed to use Linear Programming rather than bid stack method
- Generator agents have been pre-programmed to include risk taking behavior
- Price cap has been set to $10,000.

The settings of various parameters, including the learning rate, discount factor have been omitted from this paper. Readers are advised to read the paper by Sugianto and Liao (2014) for detailed design and definitions of the state, the action and the action-selection policy.

3.1 The Dispatch (Linear Programming) Engine

The dispatch engine agent can be perceived as the Power Exchange in the electricity market. It accepts the bids from each generator agent, extracts the load forecasts in each bus (node) and determines the most economic schedule (pricing) for electricity supply using Linear Programming algorithm. In essence, the LP algorithm has been imposed with several constraints: (1) generator physical constraints, such as minimum and maximum capacities, ramp rate, (2) economic constraints, such as generators' price and quantity bid in each band, (3) transmission losses and limits, and (4) regional demand.

Equation (1) shows the Matlab built-in function that implements the LP model in the dispatch engine. Equation (2) shows the minimization problem subjected to the constraints shown in Equations (3) to (5).

$$x = linprog(f, A_{ineq}, B_{ineq}, A_{eq}, B_{eq}, ub, lb) \quad (1)$$

$$\text{Solve} \quad \min_{x} f^{T} \cdot x \quad (2)$$

subject to:

$$A_{ineq} \ x < B_{ineq} \quad (3)$$

$$A_{eq} \ x = B_{eq} \quad (4)$$

$$lb \leq x \leq ub \quad (5)$$

where x is a vector of blocks of (electrical) energy offered by generators and transmission flows on each transmission line; f is a vector of cost of energy on each block offered by generators; Aineq and Bineq define the constraints of generators; Aeq and Beq define the balance equation between supply vs demand and in-flow vs out-flow of electricity; ub and lb define the constraints on energy blocks and transmission lines.

Given that the Java-Bali network grid contains four regions, namely Jakarta-Banten, West Java, Central Java-DIY and East Java-Bali, it should also be noted that the dispatch engine optimizes the whole market, and not per-region basis. The spot price for each node is determined using sensitivity analysis of the demand at each node by taking the derivative of the objective function due to a small change of demand at each node.

A database containing half-hourly demand data and costing data has been included to facilitate the generator agents and the dispatch engine agents. The database is used by the generator agents to look up the load demand so that agents can formulate their bids and submit them to the central pool.

In summary, the dispatch agent calculates the clearing price and announces it to all generator agents. Subsequently, the generator agents calculate their profit and learn from the bidding experience to improve their future strategies.

3.2 Generator Agents' Bid Formulation

Generator agents form their bid curve based on their costing function. Given that generation cost functions are classified as confidential data, for the purpose of simulation, these functions are derived from generation technology characteristics of plant types installed in the Java Bali region. Plant-specific characteristics such as heat rates, capital cost, fixed operation/maintenance cost, variable operation/maintenance cost and fuel prices have been used to determine generators' cost functions. Table 4 displayed the plant specific characteristics to derive the generators' cost functions. These values were published in the PLN system planning report (RUPTL) in Prasetyo (2009) and also available in the US Energy Information Administration (EIA, 2008).

Generation cost is composed of fixed cost and variable cost. When competing in the market, gencos would have the incentives to operate and maintain their power plants with efficient heat rates and high availability factor in order to be dispatched and earn more revenue.

Generator agents submit their bids following ten price-quantity band format. The price component ranges between \$0 and the highest historical bid price. In segregating this range into ten bands, the percentile method has been used. Equation (6) shows the formula used to calculate the value of the second to the ninth value for the price bands. Some randomness are factorized into the bidding formulation using the *rand()* built-in function.

$$P_i = p_i \times (1 + rand(\,)) \times (p_{i+1} - p_i)/p_i \quad (6)$$

$$\text{where } 1 < i < 10$$

Pi is the bid price, pi is the current percentile. Each agent can access all previous price and quantity historical bidding data. Thus, the 10th, 20th, 30th, up to 100th percentile values are known.

In addition, the bid curve is formed to be either a steep curve or a flat curve to exhibit bidding behavior of the generator agents. A risk taker agent formulates a steeper supply bid while a risk averse agent formulates a flatter supply bid. Variation in the steepness (slope) of the bid curve can be achieved by using k parameter in calculating the quantity component of the bid curve.

While the base quantity (Q1) is the minimum stable load, the other quantity band is calculated using Equation (7) only when the total quantity submitted are still within the maximum generating capacity of the power plant.

Equation (7) shows the formula used to calculate the value of the

$$Q_i = (P_i - k \times v)/(2 \times k \times f) \quad (7)$$

where $1 < i < 10$

Qi is the bid quantity, k is the risk factor, v is the variable cost coefficient and f is the fixed cost coefficient.

Table 4. Power plant costing

Generation Technology	Capacity (MW)	Minimum stable generation level (%)	FOR (%)	Capital Cost ($/kW)	Heat Rate (kcal/kWh)	FOM ($/kW/yr)	VOM ($/MWh)	Fuel Price ($/MMBtu)
Thermal-coal	600	50%	13%	1400	2388	26.79	4.46	1.77
CCGT-gas	750	40%	12%	930	1800	12.14	2.01	7.09
OCGT-oil	200	0%	15%	550	3440	11.78	3.47	15.05

4. Simulation Results

This study proposes to examine the suitability of implementing a competitive market for the Java-Bali system using an agent based simulation platform. The half-hourly demand data from the region has been used in the simulation. The simulation scenario includes ten competing players with thermal and non-thermal plants bidding at roughly marginal cost. The scenario has been repeated 20 times and consistent trend in results have been observed in these repeated simulations.

As can be seen from Table 5, there is an increase in spot price when the proportion ratio of supply-to-demand is approximately 68%. At a higher level of ratio, demand becomes inelastic, giving high leverage for suppliers to gaming behaviour.

Furthermore, a competitive market can work efficiently only if players have roughly equal share on the traded commodity. The simulation results listed in Table 6 indicates the Pareto Optimality in the market for ten competing companies with thermal generators, when all competing generators with uniform characteristics (thermal plants, fixed cost coefficient *(f)* = 8.1, variable cost coefficient *(v)* = 0.0063) bid at marginal cost, yielding a spot price of $36.78. It also shows the impact on the spot price when a competing generator has increased market power and bid to maximize its profit. The risk factor *(k)* models the supply bid curve: $k = 1$ represents bidding at marginal cost, while increasing k value represents more aggressive bidding behaviour to maximize generator's profit.

Table 5. Trend in spot price with varying supply-demand ratio

Proportion to Supply	Spot Price ($)
85%	67.64
81%	47.61
75%	45.20
71%	45.20
69%	39.88
67%	16.96
65%	11.96
63%	11.96
60%	11.96
55%	0.50
50%	0.49

Table 6. Spot price and generator's profit with market power

Bid Factor (k)	Market Share 30%		Market Share 40%	
	Price	Profit	Price	Profit
1	36.78	32618.91	50.35	70066.45
1.1	37.22	33398.44	50.35	70066.45
1.2	37.22	32532.50	9005.18	26943493.24
1.3	37.22	31319.06	9005.19	26943493.24
1.4	37.65	31303.79	9005.19	26943493.24
1.5	39.25	30596.37	9005.19	26943493.24
1.6	39.25	29571.27	9005.20	26943493.24
1.7	39.25	27889.65	9005.20	26943493.24
1.8	39.25	26272.42	9005.20	26943493.24

5. Concluding Remarks

This paper has provided an overview of the trend and implications of electricity industry around the world. Specifically, the paper discussed the Indonesian case – focusing on the trend and main challenges in this country. The study has identified the current issues faced by the Indonesian electricity industry to be: overcoming electricity shortages, ensuring the supply-demand balance, improving the elasticity for electricity, ensuring even distribution of electrification, as well as enhancing the electrification ratio. These issues are hard to deal with because they are inter-related and require long term solution. Power shortage can be overcome considerably by ensuring adequacy and reliability of supply. In other words, it is crucial for the Indonesian electricity industry to both ensure sufficient generation capacity for supply and manage demand. Hence, this study proposes to explore different industry structure to partly overcome the electricity supply challenges. Such approach attempts to release the government from providing huge subsidy to the industry and let the market discover competitive electricity price. The competitive price also serves as an indirect signal to customers on their usage. Hence, the combination of supply installation and demand side management is considered effective to ensure sustainable electricity supply in Indonesia.

Introducing competition in the electricity industry must take careful measures due to the non-storability nature of electricity, namely the supply and demand balance must be maintained continuously. Thus, following similar research in other parts of the world, this study proposes to use a computerized simulation platform as a mechanism to assess the level of readiness for electricity network grid. Using this approach, generation companies (gencos) have been modelled as agents that bid their supplies into the competitive market. Agent based model enables the simulation of agents' bidding to recreate and predict the market behaviour, including spot price dynamics. This computerized platform has been developed using object oriented programming, employing an SQL Server database to host hourly demand data of Java-Bali system, and Matlab to serve as the optimization dispatch engine. In this study, the Java-Bali system has been chosen as the region to conduct the experiment. By using the power plant characteristics and cost function data, the bidding behavior and pricing dynamics can be observed.

In a perfectly competitive market where suppliers cannot influence prices, they have the incentive to offer their products at the marginal cost in order to maximize their profits. Previous research (Gross and Finlay, 1996) suggested that an optimal strategy in a perfectly competitive market is bidding at marginal costs. In real life, the electricity market is illiquid and is not perfectly competitive. This is due to limited number of generating companies (gencos), transmission constraints, limited depth in consumption (or lack of diversity in end users), and legacy agreements that limit competition. Therefore, the electricity market is best represented by an oligopolistic model of competition. Gencos can have significant market share in a regional market, and thus, may possess market power to influence the market price. Moreover, gencos can exercise their market power during (1) increased load demand, (2) extreme temperatures that lead to peaking demand at certain seasons, (3) unplanned outage of a generator or network element and (4) transmission congestion. In fact, gencos can withdraw some of its capacity from the market and still gain more profit since its offer bid can outweigh its loss of market share. This pattern is consistent with the empirical analysis of the strategic bidding behavior of generators reported by other researchers (Wolfram, 1997; Sugianto and Liao, 2014).

This study concludes that careful measures must be put in place for a competitive electricity market to be effective, reliable and sustainable. A sufficient supply capacity accompanied by transmission adequacy and reliability of supply must be available in the region to make sure that gaming strategy will not lead to inflated price. The finding of this study indicates that competitive electricity pricing is not yet viable in the Java Bali region. Apart from ensuring comparable generating capacities of the players, it is important to install additional generations in the region.

Likewise, consumers need to be educated for wise electricity usage that minimizes carbon foot print. A high elasticity factor indicates that the use of electricity is unproductive and inefficient. A study on the relationship between electricity consumption and economic growth concludes that in Indonesia the economic growth has a uni-directional causality effect on electricity consumption (Yoo, 2006). Therefore, conservation policy in Indonesia will not impede Indonesian economic growth.

Last but not least, the state (through the state-owned company) also needs to carefully plan the installation of power plants in other areas beyond the Java-Bali region. Long term agenda should maintain high electrification rate so that distribution of electricity availability is distributed evenly across the archipelago to result in even economic development in all areas of Indonesia.

Acknowledgments

The work described in this paper is part of a project funded by the Australian Indonesian Governance Research Partnership (AIGRP) grant. The author would like to acknowledge AIGRP for its supports on this project and to Dr Moeljono Widjaja for providing the data for this study. The author would also like to acknowledge Dr Kevin Liao for his assistance in this research.

References

Achterstraat, P. (2008). *New South Wales Auditor-General's Report - Focusing on Electricity.* Audit Office of New South Wales, Australia.

Amin, M. (2002). Restructuring the Electric Enterprise: Simulating the Evolution of the Electric Power Industry with Intelligent Adaptive Agents. In Market Analysis and Resource Management. Faruqui, A. and Eakin, K. (Eds.), Kluwer Publishers.

Bagnall, A. J., & Smith, G.D. (2005). A Multi-Agent Model of the UK Market in Electricity Generation, *IEEE Transactions on Evolutionary Computation*, *9*(5), 522- 536. http://dx.doi.org/10.1109/TEVC.2005.850264

Barnett, J., & Shurtleff, S. (2007). Electricity Deregulation: Taking the Next Step, Brief Analysis No.592, August 9, National Center for Policy Analysis.

Bunn, D., & Oliveira, F. (2003). Evaluating Individual Market Power in Electricity Markets via Agent-Based Simulation. *Annals of Operations Research, 121*, 57–77. http://dx.doi.org/10.1023/A:1023399017816

Central News Agency (2008). UK, Taiwanese experts collaborate on wind power. in Taiwan News, p2. Retrieved November 5, 2008, from http://www.etaiwannews.com/etn/news_content.php?id=779811

EIA (2008). Assumptions to the Annual Energy Outlook 2008. Retrieved June 15, 2009, from http://www.eia.doe.gov/oiaf/archive/aeo08/index.html

Entriken, R., & Wan, S. (2005). "Agent-Based Simulation of an Automatic Mitigation Procedure" CD ROM Proceedings of the 38th Hawaii International Conference on System Sciences.

Erev, I., & Roth, A. E. (1998). Predicting how people play games: reinforcement learning in experimental games with unique, mixed-strategy equilibria. *American Economic Review, 88*(4), 848–881.

Gallego L., Duarte O., & Delgadillo A. (2008). *Strategic bidding in Colombian electricity market using a multi-agent learning approach.* In IEEE/PES Transmission and Distribution Conference and Exposition; August 2008; Bogota, Latin America: IEEE. pp. 1-7.

Gross, G., & Finlay, D. J. (1996). *Optimal bidding strategies in competitive electricity market.* Proceedings of the 12th Power Systems Computation Conference (PSCC), Dresden: CD-ROM.

Huang, X., & Liu, X. D. (2009). Modeling and simulation of bidding activities of power generation companies by multi-agent. In International Joint Conference on Computational Sciences and Optimization (CSO); April 2009; Sanya. pp. 466-470.

Koesrindartoto, D. P., Sun, J., & Tesfatsion, L. (2005). "An Agent-Based Computational Laboratory for Testing the Economic Reliability of Wholesale Power Market Designs." Proceedings of Vol. 1, IEEE Power

Engineering Society General Meeting, San Francisco, CA: 931-936.

Newbery, D. M., & Pollitt, G. M. (1997). The Restructuring and Privatisation of the CEGB- Was it worth it. *Journal of Industrial Economics, XLV*(3), 269-303.

Outhred, H. (2000). The Competitive Market for Electricity in Australia: Why it Works so Well. Proceedings of the 33rd Hawaii International Conference on System Sciences, pp.1-8. http://dx.doi.org/10.1109/HICSS.2000.926760

Papageorgiou, G. (2004). Modelling of Electricity Markets Using Software Agents. A dissertation submitted to the University of Manchester Institute of Science and Technology for the degree of Master of Science in Electrical Power Engineering, Department of Electrical Engineering and Electronics, UMIST.

Prasetyo, D. (2009). Pemaparan Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) 2009-2018 PT PLN, MKI Workshop, Jakarta, 17 March 2009.

Ritschel, A., & Smestad, G. P. (2003). Energy subsidies in California's electricity market deregulation. *Energy Policy*, (31), 1379-1391. http://dx.doi.org/10.1016/S0301-4215(02)00197-0

Sheble G. B., & Gutierrez-Alcaraz G. (2012). Generation companies' adaptive bidding strategies using finite-state automata in a single-sided electricity market. *European Transactions on Electrical Power*, (22), 771-786. http://dx.doi.org/10.1002/etep.605

Sugianto, L. F., & Liao, K. (2014). Comparison of Different Auction Pricing Rules in the Electricity Market, *Modern Applied Science*, *8*(1), 147-163. http://dx.doi.org/10.5539/mas.v8n1p147

Sutton. R. S., & Barto. A. G. (1998). Reinforcement learning: An introduction. MIT Press.

Tellidou A. C., & Bakirtzis A. G. (2007). Agent-based analysis of capacity withholding and tacit collusion in electricity markets. *IEEE T Power Syst,* (22), 1735-1742. http://dx.doi.org/10.1109/TPWRS.2007.907533

Thorncraft, S. R., & Outhred, H. (2007). Experience with Market-Based Ancillary Services in the Australian National Electricity Market. Proceedings of the Power Engineering Society General Meeting, pp1-9.

Veselka. T., Boyd. G., Conzelmann. G., Koritarov. V., Macal. C., North. M., Schoepfle. B., & Thimmapuram. P. (2002, October 6-8). Simulating the behavior of electricity markets with an agent-based methodology: the electricity market complex adaptive system (EMCAS) model, International Association for Energy Economists (IAEE) North American Conference. Vancouver, B.C.

Wells, J. (2005). Electricity Restructuring: Key Challenges Remain. Government Accountability Office Highlights, GAO-06-237, pp.1-22.

Wilson, N. (2007). Electricity Price Hits Maximum Level Allowed. The Australian Business, Business Section, 19 November 2007.

Wolfram, C. D. (1997). Strategic Bidding in a Multi-Unit Auction: An Empirical Analysis to Bid to Supply Electricity, Working Paper 6269, National Bureau of Economic Research, Cambridge.

Yoo, S. H. (2006). The causal relationship between electricity consumption and economic growth in the ASEAN countries, *Energy Policy*, *34*(18), 3573-3582. http://dx.doi.org/10.1016/j.enpol.2005.07.011

Copyrights