Optimal Bidding Price Strategy in Electricity Auction for New Capacity in Malaysia Considering Uncertainty

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Abstract— The objective of this paper is to find the optimal biding price in electricity auction for new power - plants in Malaysia. This strategy is applied to three most common generation technologies which is coal, gas-fired (CCGT), and nuclear. It is important for the generating company to determine the minimum bid prices that it should submit in the auction in order to ensure that the investment would be profitable and meet the Minimum Acceptable Rate of Return (MARR) aimed by the company. The uncertainty such as fuel cost, overnight cost, operation and maintenance (O&M) cost and utilization factor are considered in the model. The effect of these uncertainties on the bid prices is studied using 1) sensitivity analysis and 2) probabilistic analysis. Results show that the bid prices of nuclear is more sensitive to the changes in investment cost, O&M cost and utilization factor and less sensitive to the fuel cost than coal and CCGT. On the other hand the bid price of CCGT is more sensitive to the fuel cost. The sensitivity of coal plant shows result somewhere in between the nuclear and CCGT. -

Index Terms-generation investment, auction, uncertainty, sensitivity analysis, probability model.

I. INTRODUCTION

Throughout the past decades, Malaysian electricity industry has gone through significant industrial revolution due to rapid growth in economic. The industry transformed from the beginning of isolated plants supplying mining operations into localised district supply systems supplying the commercial, industrial and domestic sectors. This was followed by the development of central power stations, accompanied by construction of transmission lines and a national grid to keep the lights on throughout the nation.

The industry began with the private generation companies in year 1900 mainly in supplying the tin mining industry. The pioneer were Malacca Electric Light Co. Ltd. (1913), Huttenbachs Ltd. (1916), Perak River Hydro Electric Co. Ltd. (1926) and Kinta Electric Distribution Co. Ltd. (1928). In 1949, Central Electricity Board (CEB) was developed to provide electricity to peninsular Malaysia. CEB was then renamed as National Electricity Board (NEB) in 1965. The revolution followed by corporatization of NEB in July 1990 and again changed its name to Tenaga Nasional Berhad (TNB). As the demand increased rapidly as state in [1] which is demand for electricity increase 4.7 % per year, the government was unable to build power generation fast enough. During that time, privatization was an attractive alternative. TNB was privatized and listed on the Malaysian Stock Exchange in 1992.

Independent power producer (IPP) was introduced in year 1993 through licenses awarded by government to Build, Operate and Own (BOO) the power plants in order to speed up the power generation. However, transmission and distribution operation is solely under the purview of TNB. In 2001 the Energy Commission of Malaysia was established as a new regulator in Malaysia as preparation to face the new challenge of electricity supply liberalization [7].

As an effort of bringing Malaysia towards competitive electricity industry, Energy Commission has introduced a new competitive bidding exercise for new power plants in 2011. Energy Commission is targeting 4500MW of new capacity by 2016 via competitive bidding to replace capacity from the 1st generation power purchase agreement which will be expired from 2015 to 2017 and to cater for future load growth [2]. The introduction of competitive bidding exercise for a new power plant has exposed the IPPs and generating companies to a much riskier and uncertain investment environment. The decision on what price to bid in order to make sure the plant would be profitable over its lifetime has become a main concern of generating companies.

This paper proposes a model to find the optimal bid price in the auction for a new capacity in Malaysia considering various uncertainties. Two analysis have been performed i.e. 1) sensitivity analysis and 2) probabilistic analysis considering uncertainty in the investment cost, the utilization factor, the fuel cost and the O&M cost. The model has been tested to find the bid prices of different power generation technologies i.e. 1) nuclear, 2) coal and 3) CCGT.

II. The Proposed Model

A. Optimum Bid Prices

This paper estimate the minimum bid that the new plant should submit to recover all of its cost, where at this point the NPV is equal to zero. The higher the NPV, the more profit will be obtained by the company.

The Net Present Value (NPV) is expressed in (1) as follow:

$$NPV = I + \sum_{n=1}^{N} \frac{CF_n}{(1+r)^n} \qquad (1)$$

where CF represents the net cash flow in year n, r is the discount rate, I is the investment cost, and N is the project lifetime.

Investment cost is incurred before the plant starts operating and is set as negative cash-flow in the calculation. To calculate the price, the NPV is set to zero (2) where the discount rate is equal to internal rate of return (IRR). Equation (3) shows the bid price is calculated in such a way that the investment cost is equal to the present value of the revenue. The production cost and the revenue of the investment are assumed constant over the plants lifetime. It is also assumed that the plant will be paid at its bid price for the energy that it will produce.

$$0 = I + \sum_{n=1}^{N} \frac{CF_n}{(1+IRR)^n} \qquad (2)$$

$$I = \sum_{n=1}^{N} \frac{CF_n}{(1+IRR)^n} \qquad (3)$$

The investment cost, the annual production, the production cost, the annual revenue and finally the bid prices are given in the following equations:

$$I = Ovr\_cst \,.\, Opt \qquad (4)$$

$$P\_year = utl\_fct \,.\, Opt \,.\, T \qquad (5)$$

$$PC\_year = P\_year \,.\, (FP.\, HR) \qquad (6)$$

$$AR = CF + OM + PC\_year \qquad (7)$$

$$BP = AR/P\_year \qquad (8)$$

Ovr_cst	overnight cost (RM/kW)
Opt	plant capacity (MW)
P_year	production per year (MW/year)
Utl_fct	efficiency of plant (%)
FP	fuel price (RM/MBtu)
HR	heat rate (MBtu/MWh)
AR	annual revenue (RM)
T	time (h)
NCF	net cash flow (RM)
OM	O&M cost (kW/year)
PC_year	production cost per year (RM/MWh/year)
BP	biding price (RM/MW)

These equations can be used for all type of thermal plants that has a long time period contract in supplying electricity. Although generating company could estimate the bid price using the equations above, by doing it deterministically does not guarantee their investment would be profitable. This is because the parameters are uncertain which could influence the annual production of the plant, hence its annual revenue. Therefore in this paper, the basic model above is extended to consider uncertainty in the investment cost, the utilization factor, the fuel cost and the O&M cost using sensitivity analysis and probabilistic analysis. The effect of changing these parameters on the bid prices of different technology is analyzed.

B. Investment Uncertainties

In this paper the uncertainty parameters such as fuel price, overnight cost, fixed operation and maintenance (O&M) cost and utilization factor/efficiency of plants operation have been considered in the model.

Since each technology has its own technical and cost characteristics, each of the uncertainty considered above would affect the bid price of different technology differently.

Following describes the characteristics of the uncertainties for different power generation technologies.

i. Fuel cost depends on the type of the fuel used. This paper considers three type of generating technology i.e. gas-fired, coal-fired and nuclear. Comparing these three thermal plants, natural gas has the highest fuel cost. The price of natural gas is more volatile compare to coal and uranium for nuclear plant. The price of natural gas follows the trend of crude oil price as shown in Table 1 [3]. The volatility of the gas price is the biggest source of uncertainty for investment in CCGT.

ii. Overnight cost is defined as the total cost of building before the plant start operating and producing electricity. Extending the time of construction might lead to increase in the cost. Nuclear plant has higher investment cost compare to coal and CCGT plant. This plant needs to operate for long hours in order to be profitable.

iii. O&M cost is also one of the sources of uncertainties in generation investment. Similar to the investment cost, the nuclear plant has higher O&M cost than the coal and CCGT.

iv. Utilization factor is another important source of uncertainty that must be considered in generation investment. Utilization factor is the ratio of the time that the plant operated in a year. Ideally the plant should operate at full capacity at all times. However, in practice, this is not possible because the plant has to be shut down periodically for maintenance and failures. The unpredictable outages would affect the energy production of the plant and hence its revenue. In this study since the marginal cost of nuclear plant is usually lower than the coal and CCGT, it is assumed that nuclear plant has slightly higher utilization factor than coal and CCGT plant.

Year	Time	Crude Oil Spot Prices	Nature Gas Price	Year	Time	Crude Oil Spot Prices	Nature Gas Price
1988	13	15.97	4.63	2000	25	30.37	6.59
1989	14	19.68	4.74	2001	26	25.93	8.43
1990	15	24.5	4.83	2002	27	26.16	6.63
1991	16	21.54	4.81	2003	28	31.07	8.4
1992	17	20.57	4.88	2004	29	41.49	9.41
1993	18	18.45	5.22	2005	30	56.59	11.42
1994	19	17.21	5.44	2006	31	66.02	11.65
1995	20	18.42	5.05	2007	32	72.2	14.35
1996	21	22.16	5.4	2008	33	100.06	13.2
1997	22	20.61	5.8	2009	34	50.6	12.3
1998	23	14.39	5.48	2010	35		
1999	24	19.31	5.33	2011	36		

Table 1: International crude oil spot prices (US dollars per barrel) and International nature gas price US Dollar /MMBTU

C. Sensitivity Analysis and Probabilistic Analysis

Sensitivity analysis is considered by changing the uncertainty parameters by +-20% from its base value. The sensitivity of the bid price of each technology towards these parameters is then observed.

The introduction of probabilistic analysis extends the classic economic theory to take into account the risk and uncertainty in determining the bid prices of the investment plant. In this technique, the input parameters to the financial model are defined as statistical distributions to represent uncertainties. A Monte-Carlo simulation [4] can be used to determine the probability distribution of the bid prices. This is done by randomly pick the value of the input parameters within the predefined distribution, and the corresponding value of the bid prices is calculated by the financial model. The process is repeated for example 1000 times to get a probability distribution of the bid prices as shown below.

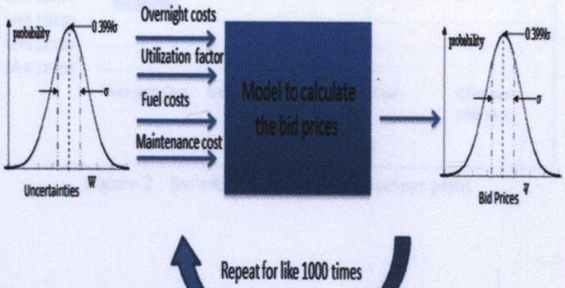

Figure 1 : Probabilistic Model Using Monte Carlo Simulation

III. TEST DATA

The technical and cost parameters of the three technologies are shown in Table 2 [5]. On the other hand, the mean and standard deviation of the uncertainty parameters are shown in Table 3 [6].

Parameter	Unit	Nuclear	Coal	CCGT
Technical Parameter				
Net capacity	MW	500		
Heat rate	MBTU/MWh	31.2	25.8	21
Construction period	years	5	4	2
Plant life time	years	40	30	20
Cost Parameter				
Overnight cost	RM/kW	5430	3525	1356
Fixed O&M	RM/kW/yr	171.42	61.89	42.87
Fuel cost	RM/Mbtu	1.65	6.18	15.72
Utilization factor	%	90	85	80

Table 2: Technical and cost characteristic of investment plant

Normal Distribution Parameter	Technology	Mean	Standard deviation
Overnight cost (RM/kW)	Nuclear	5700	1000
	CCGT	1425	142.5
	Coal	3700	370
Fuel cost (RM/Mbtu	Nuclear	1.75	0.5
	CCGT	16.5	5
	Coal	6.5	1
Fixed O&M (RM/kW/yr)	Nuclear	180	18
	CCGT	45	4.5
	Coal	65	6.5
Utilization factor	Nuclear	0.9	0.1
	CCGT	0.8	0.1
	Coal	0.85	0.1

Table 3: Random variable Normal Distribution parameter

IV. RESULT

. Table 4 shows the bid prices of each of the technology considering the base value. It is shown that for the nuclear plant to be profitable, it should submit a minimum bid of 148.92RM/MW. On the other hand, since the CCGT is considered operated with lesser hour than nuclear and coal, it has to bid higher i.e. 281.56 RM/MW. The minimum bid price for coal is between nuclear and CCGT.

Technology	Price (RM/MW)
Nuclear	148.92
CCGT	281.56
Coal	246.44

Table 4 : Biding price by considering base value

Figure 2, 3 and 4 shows the results of sensitivity analysis for the three technologies. Nuclear power plant is sensitive to the overnight cost because it requires a huge capital cost. The second factor that influence the biding price is O&M cost. However, it is less sensitive to the fuel cost compare to the coal and CCGT plant.

On the other hand, CCGT is more sensitive to the change in the fuel cost than nuclear and coal. This is shown in Figure 8. Having a lower investment cost and O&M cost, the CCGT is less sensitive to the uncertainty in the overnight cost, utilization factor and O&M cost than nuclear and coal plant.

The sensitivity analysis of coal shows result somewhere between nuclear and CCGT. All the parameters are important for the bid prices of the coal plant.

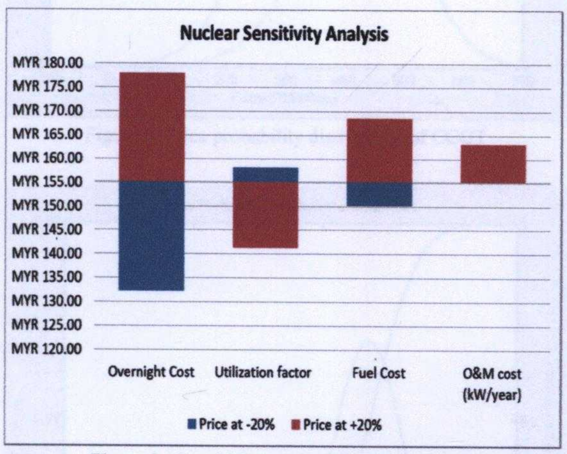

Figure 2 : Sensitivity analysis for nuclear plant

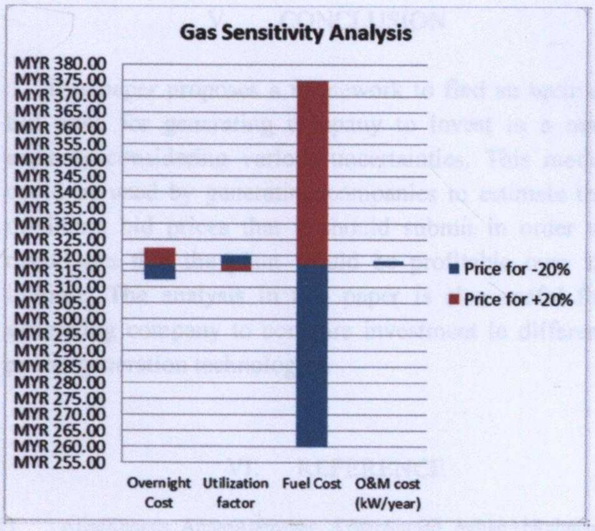

Figure 3: Sensitivity analysis for CCGT

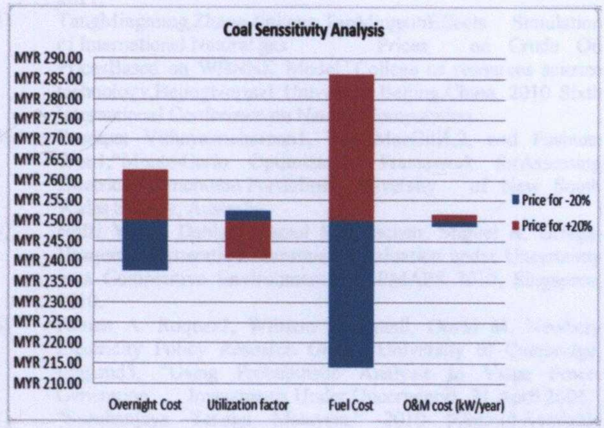

Figure 4: Sensitivity analysis for coal-fired

The probability density function (PDF) and cumulative distribution function (CDF) of all the technologies are shown in Figure 5, 6 and 7 respectively. Comparing the bid price distribution of the three technologies, nuclear plant has the lowest deviation of the bid prices considering all the uncertainties. This shows that investing in the nuclear plant is less risky. This is shown in Figure 5. On the other hand, CCGT has the largest distribution of the bid prices among all the technologies considered. This shows that CCGT is a much riskier investment compare to nuclear and coal. The high deviation of the fuel cost is the main factor that contributes to the bigger distribution of the bid price. A similar trend as in sensitivity analysis is found for the coal where the deviation of the distribution of the bid prices is between the nuclear and CCGT.

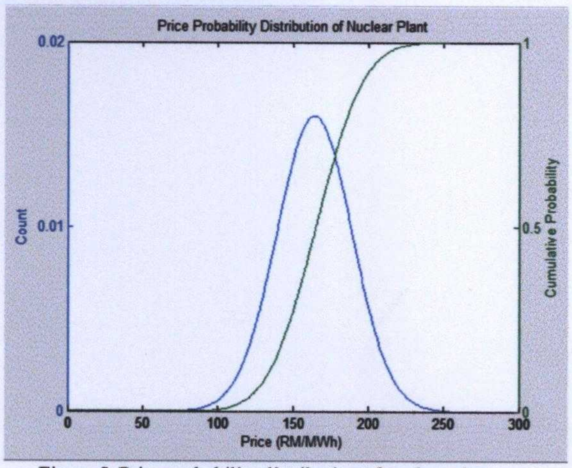

Figure 5: Price probability distribution of nuclear plant

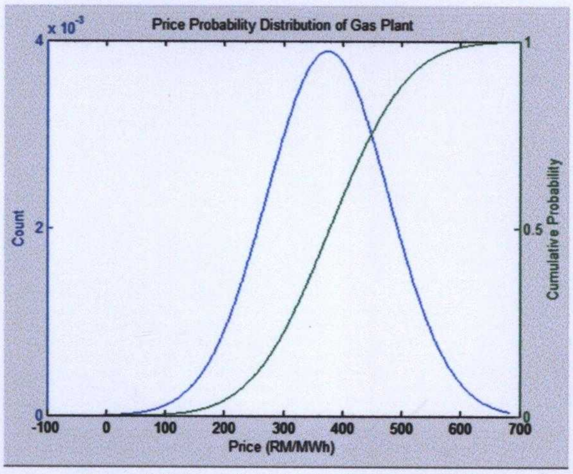

Figure 6: Price probability distribution of CCGT

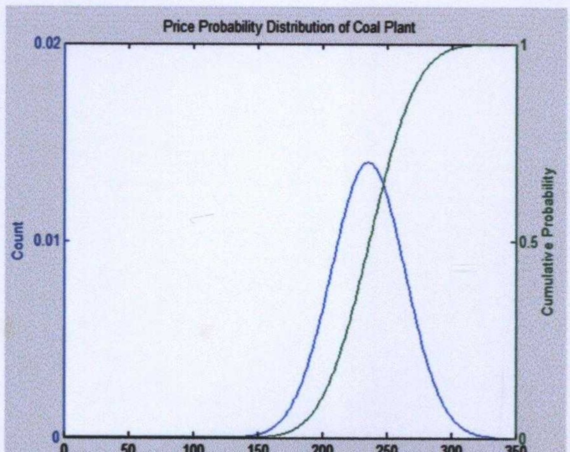

Figure 7: Price probability distribution of coal-fired

V. CONCLUSION

This paper proposes a framework to find an optimal bid price for generating company to invest in a new capacity considering various uncertainties. This model could be used by generating companies to estimate the minimum bid prices that it should submit in order to make sure that the plant would be profitable over its lifetime. The analysis in this paper is also useful for generating company to compare investment in different power generation technologies.

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