Modeling Electricity Tariff Scheme for Gas Engine Power Plant by Considering Operation Risks

Nurhadi Siswanto, Firda Nur Rizkiani, Stefanus Eko Wiratno
Department of Industrial and Systems Engineering
Institut Teknologi Sepuluh Nopember
Surabaya 60111, Indonesia
siswanto@ie.its.ac.id, firda15@mhs.ie.its.ac.id, stefanus.wiratno@ie.its.ac.id

Abstract

This research discusses the determination of the electricity tariff scheme with a certain value limit on the capacity expansion plan of the gas engine power plant (GEPP). The additional GEPP will use some of the existing GEPP resources such as land, gas supply network, electricity network, and human resources. A financial model with the incremental analysis method is designed to calculate levelized electricity rates, which is divided into 4 cost components, namely: investment costs (A), fixed operating and maintenance costs (B), fuel costs (C), and variable operating and maintenance costs. (D). Monte Carlo simulation is used to conduct a risk assessment due to the uncertainty of inflation, heat rate and availability factors. The results of the analysis shows that to achieve the electricity production target, it can be done through a combination of using other brands of machines, selecting gas suppliers, recalculating gas transportation costs, and reducing maintenance costs by performing a long-term maintenance contract (LTMC). This study considers most of the parameters that influence the determination of the tariff scheme, so that it can be used for other generator tariff scheme determination models. The result of the research on determining the tariff scheme for GEPP indicates that a tariff adjustment needs to be applied, because it has considered the uncertainty over changes in the inflation rate and the exchange rate.

Keywords
Electricity tariff, incremental analysis, financial feasibility, and Monte Carlo Simulation

1. Introduction
Electric power has a very important and strategic role in realizing national development goals. The process of deregulation and competitive markets have been reshaping of the traditionally monopolistic and government-controlled power sector. In many countries, electricity is now traded under market rules using spot and derivative contracts. However, electricity is a very special commodity. It is economically non-storable and power system stability requires a constant balance between production and consumption (Kaminski, 2013; Shahidehpour, Yamin, & Li, 2002). Electricity demand tends to increase proportionally with regional economic and population growth in future. Generally, the electrical problem will arise in areas where an interconnect electricity system is unavailable or independently fulfill the electricity demand due to an unbalance between supply and demand like in one island in Indonesia.

The island is situated on the Java sea and separated from main Java Island, making their electricity network is isolated from the Java-Bali electricity system. Therefore, the electrical power on the island must be carried out independently to fulfill its electricity demand. The consumption rate of electric energy in the island will increase by 5.01% and estimated that the peak load will increase to 7-8 MW in 2022. Hence, the state electricity company is currently planning to increase the electricity capacity to anticipate future increases in electricity loads (PT PLN (Persero), 2013).

The provision of electricity in the island is supplied by a 3.5 MW diesel power plant (DPP) and a 3 MW gas engine power plant that is more reliable than DPP even though the electricity tariff is more expensive. According to data, the electricity tariff for 3 MW GEPP is 10% higher than the one of DPP per kWh. Based on the National Energy Policy, the use of natural gas as primary energy is still relatively low (Dewan Energi Nasional Republik Indonesia, 2014). Therefore, it is necessary to increase the capacity of the GEPP as much as 2 MW. According to company data, the electricity tariff for this additional capacity must be cheaper than the DPP electricity tariff because of several resources that can be used together such as land, gas supply network, electricity network, and human resources.

Researches on modeling electricity tariff scheme have been carried out by many previous researchers. For example, Aggarwal et al (2009), Anbazhagan and Kumarappan (2012), Azadeh et al (2013). This research, especially for the case in Indonesia, has been carried out by Riusxander and Sumirat (2013) and Maksum and Rivai (2015). Riusxander and Sumirat (2013) conduct the feasibility study for a gas power plant in Muara Enim regency. The modeling electricity tariff research in their study uses Monte Carlo Simulation to design the distribution of risk and uncertainty of plant operations that are considered in calculating electricity tariff. The other study, Maksum and Rivai (2015) conduct the feasibility study for small scale coal steam power plant.

Commonly used methods in financial analysis and investment feasibility study are including breakeven point (BEP), payback period (PP), net present value (NPV), internal rate of return (IRR), and R/C ratio. All these methods are used to determine the financial performance of the investment that will be issued. NPV and IRR method is the best method to give an illustration of the profitability of an investment, because these methods consider the time value of money as the main aspect (Rangkuti, 2012). The financial indicators that are used in this research are PP, NPV, and IRR.

In this study, the calculation of electricity tariff for gas engine power plant uses the incremental analysis and Monte Carlo Simulation method. Incremental analysis is a calculation of as-is cash flow and to-be cash flow in which changes in capital expenditure, operational expenditure, and income from investment alternatives. In the additional investment of 2 MW GEPP there are additional revenues, investment costs, fuel costs, operational and maintenance costs. The additional cost for this additional capacity must be adjusted to the predetermined upper limit of electricity rates. If the electricity tariff is more expensive than the DPP tariff, then it is necessary to conduct an evaluation to reduce the tariff. Consequently, it must consider the risk and uncertainty of plant operations that carried out by Monte Carlo Simulation. The derivation of availability factor, the derivation of heat rate or consumption gas efficiency, and inflation rate uncertainty are the risks of operation considered in this study. The main purpose is to provide the electricity tariff that can achieve its target. We propose three electricity tariff schemes that can attain our goal. The rest of this study organized as follows. We first provide the methodology of this study, followed by computational the electricity tariff model, results and discussion. Finally, conclusions are discussed in Section 4.

2. Methodology

The methodology of this study is shown in Figure 1. The first step is data collection which includes unit specification data, investment costs, operational and maintenance costs, and fuel costs for additional capacity of 2 MW GEPP. These data represent additional costs due to additional investment using the incremental analysis method to obtain electricity tariffs. Calculation of electricity tariff requires the volume of electricity demand, exchange rates, inflation rates, and margin. Once the electricity tariff is calculated, we check if it is cheaper than the DPP tariff or not. If yes, we both identify and consider the operational risks in terms of calculating the electricity tariff so that a new tariff is obtained. The distribution of operational risks is carried out by Monte Carlo Simulation. Otherwise, we identify the component cost that potential to be reduced. Finally, we check and analyze the electricity tariff based on financial indicators.

3. Computation of Electricity Tariff

Electricity tariff is influenced by the volume of electricity, fuel costs, operational costs, and investment costs. Moreover, the capacity factor and the consumption of electricity will affect as well, which is used as dividers of the total costs. Hence, the electricity tariff for each component can be obtained as described below.

3.1 Unit Generator Specification

The specification of the additional unit is shown in Table 1. The maximum capacity of this unit is 2.15 MW and has a capacity factor and self-consumption is 70% and 4%, respectively. Consequently, the net capacity is only 1.4 MW. However, this assumption has been agreed upon by the company.

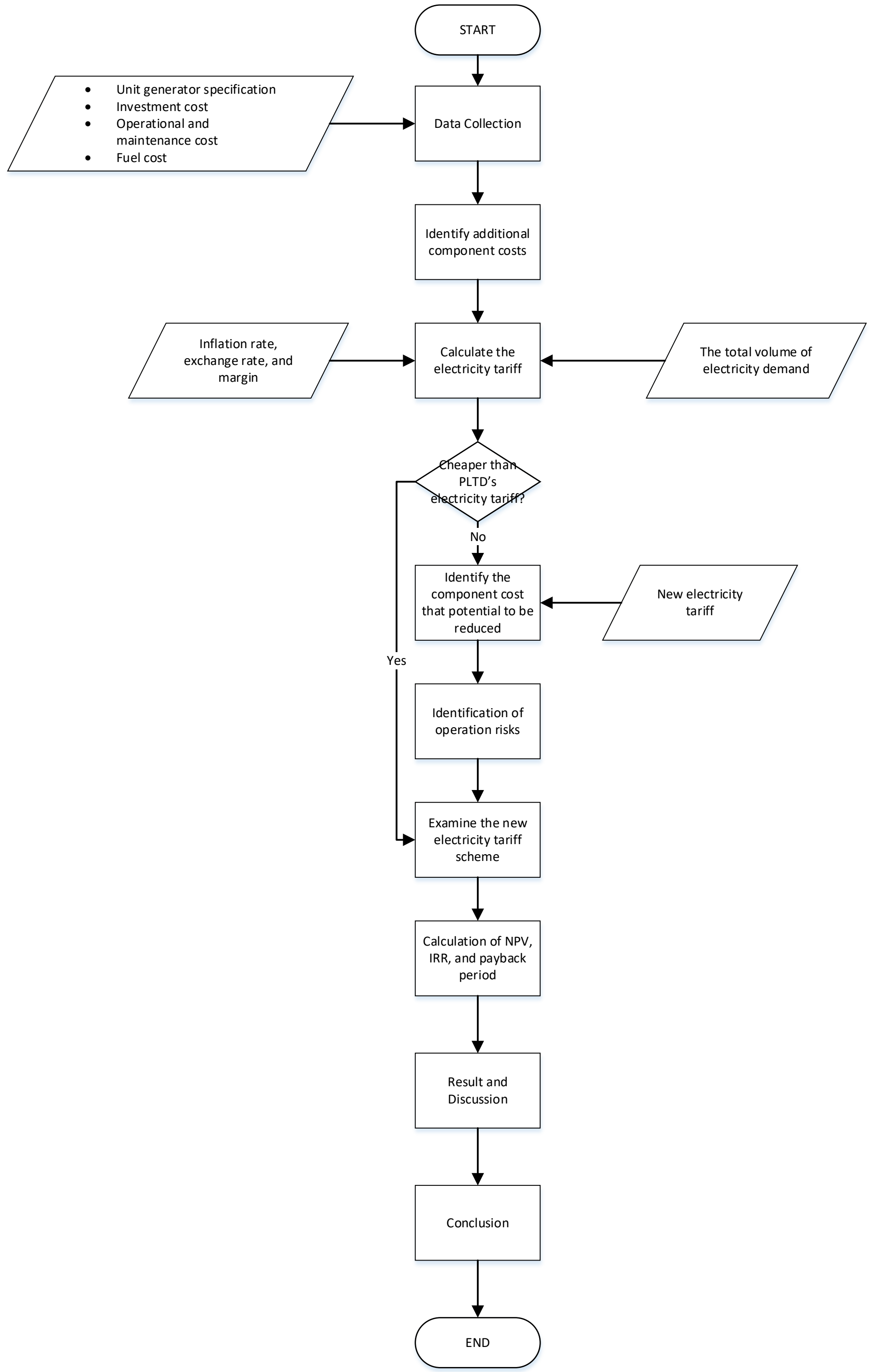

Figure 1 The Research Methodology

Table 1 The Specification of The Additional Unit

No	Description	Value
1	Maximum capacity	2.15 MW
2	Capacity factor	70%
3	Self-consumption	4%
4	Availability factor	85%
5	Operation day	365 days/year
6	Operation hour	24 hours/day
7	Fuel price	USD 7.0
8	Exchange rate	IDR 14,302/USD
		IDR 16,058/EUR

3.2 The Component Cost A

The component cost A or investment cost consists of (i) gas engine price, (ii) electrical, instrument, control material, (iii) project development costs, (iv) fire protection system costs, and (v) environmental monitoring system costs. Component cost A calculation requires the total investment costs, interest rate, time planning horizon, and annual volume of electricity. Let CRF is capital recovery factor, i is interest rate, and n is time planning horizon. Then the capital recovery factor, is given by:

$$CRF = \frac{i \times (i+1)^n}{(i+1)^n - 1}$$

Given the total investment cost, CRF, and annual volume of electricity above, the component cost A can be written as

$$The\ Component\ Cost\ A\ (IDR/kWh) = \frac{Total\ investment\ costs\ \times\ CRF}{Annual\ volume\ of\ electricity}$$

3.3 The Component Cost B

The component cost B or fixed operational cost consist of (i) maintenance costs, (ii) employee costs, (iii) administrative costs, and (iv) overhead costs. To calculate the component cost B, it requires annual fixed operational costs, inflation rate, salary increase rate, and margin. Given the annual fixed operational cost and annual volume of electricity above, the component cost B can be written as

$$The\ Component\ Cost\ B\ (IDR/kWh) = \frac{Annual\ fixed\ operational\ costs}{Annual\ volume\ of\ electricity}$$

3.4 The Component Cost C

The component cost C or fuel cost consist of (i) the amount of gas required, (ii) gas price, and (iii) the transportation of gas costs. To calculate the component cost C, we require annual fuel costs and exchange rate. Given the annual fuel cost and annual volume of electricity above, the component cost C can be written as

$$The\ Component\ Cost\ C\ (IDR/kWh) = \frac{Annual\ fuel\ costs}{Annual\ volume\ of\ electricity}$$

3.5 The Component Cost D

The component cost D or variable operational cost consists of lubricant, chemicals, and consumable material costs. To calculate the component cost D requires annual variable operational costs and inflation rate. Given the annual variable operational cost and annual volume of electricity above, the component cost D can be written as

$$The\ Component\ Cost\ D\ (IDR/kWh) = \frac{Annual\ variable\ operational\ costs}{Annual\ volume\ of\ electricity}$$

Based on the above calculation, we can derive the electricity tariff by sum all the component costs.

4. Result and Discussion

The result of the calculation of the electricity tariff is shown in Table 2. Based on the result, the electricity tariff exceeds the determined tariff, but the financial feasibility of the electricity tariff indicates a good result. Hence, we conduct an electricity tariff scheme that the target rate can be achieved. As we can see, the component cost C has the largest proportion of electricity tariff. Therefore, if we can reduce those cost, then the electricity tariff may significantly decrease. As affirmation above, the gas transportation cost and the gas price are the component cost C, which can be reduced and controlled. To reduce the transportation cost, we simulate by only calculating the cost with need additional operational and rent costs because the additional capacity of the generator does not require investment cost as much as in the investment of the existing generator. Meanwhile, reducing the gas price should be done by selecting gas supplier who offers a lower price.

Table 2 The Results of The Electricity Tariff

No	Description	Value	Unit	Proportion (%)
1	Power Plant Type	GEPP		
2	Capacity	2	MW	
3	The Component Cost			
	- A	-	-	3.75
	- B	-	-	1.12
	- C	-	-	91.99
	- D	-	-	0.90
	Total Electricity Tariff	-	-	100
4	Financial Indicators			
	NPV	541,725,470	IDR	
	IRR	13	%	
	Payback period	14.49	year	

The second-largest proportion of the electricity tariff is the component cost A. This cost can be reduced and controlled as well by selecting another machine type with a lower price but almost the same quality. Finally, to achieve the target rate, it can be done by a combination of using other brands of machines which has lower prices, selecting gas suppliers, recalculating fuel transportation costs, and reducing maintenance costs by performing a LTMC.

Maintenance activity is one of the critical activities in a business especially for power plant. Maintenance activity planning must be prepared appropriately thus, will provide better reliability of the system. Types of maintenance activities are divided into three, which are preventive maintenance, predictive maintenance, and corrective maintenance. In power plant, preventive maintenance is a maintenance strategy carried out periodically to prevent failure by checking, replacing, or overhaul (completely replacing) at a specified time interval system. There is a preventive maintenance pattern that carried out by the power plant, namely To-So-To-Mo, that distinguished by scope of work and maintenance schedule. The To-So-To-Mo pattern consists of Top overhaul, Semi overhaul, Top overhaul, and Major overhaul. We suggest that performing a LTMC for these maintenances will be profitable. However, the company should make an appropriate contract with a third-party that key performance index (KPI), scope of work, and the cost are taken into account.

This study provides three schemes of scenarios that use new gas prices, transportation costs, and considering the operational risks. The differentiation among these schemes is by the selection of machine type used. The first scenario uses a Gas Machine which has the resulted price is 9.53% lower than the basic model. The second scenario has the lowest price of gas machine to others, 9.94% lower than the basic model. The third one has 8.27% than the basic model, slightly higher from the first two scenarios. From the result, we show that due to reducing the component cost C is significantly reducing the electricity tariff. The three schemes that we conduct are successfully achieved the target rate and consider the operational risks. The result of the electricity tariff scheme calculation is shown in Table 3.

Table 3 The Results of Electricity Tariff Scheme

No	Electricity Tariff Scheme	Proportion (%)
1	Scheme I (X Machine)	
	- The Cost Component A	4.14
	- The Cost Component B	3.72
	- The Cost Component C	91.15
	- The Cost Component D	0.99
	Total Electricity Tariff Compared to Base Model	- 9.53
2	Scheme II (Y Machine)	
	- The Cost Component A	3.78

No	Electricity Tariff Scheme	Proportion (%)
	- The Cost Component B	3.66
	- The Cost Component C	91.57
	- The Cost Component D	0.99
	Total Electricity Tariff Compared to Base Model	- 9.94
3	Scheme I (Z Machine)	
	- The Cost Component A	5.17
	- The Cost Component B	3.96
	- The Cost Component C	89.89
	- The Cost Component D	0.98
	Total Electricity Tariff Compared to Base Model	- 8.27

5. Conclusion

We developed a procedure and financial model to determine the electricity tariff for gas engine power plant in the context of operation risk uncertainty. Our results suggest using other machine brands, selecting gas suppliers, recalculating gas transportation costs, and reducing maintenance costs by performing LTMC to achieve the electricity target. Moreover, we show that shifting the component cost C has a significant effect on electricity tariff. From the three electricity tariff schemes that we conduct, the second scheme is the lowest electricity tariff among the others.

References

Maksum, H. and Rivai, A., 2015. Komponen Penentu harga jual tenaga listrik dari pembangkit listrik tenaga uap batubara skala kecil (PLTU B-SK) [Components Determining the selling price of electricity from small-scale coal steam power plants]. *Jurnal Mineral dan Energi*, *13*(2), pp.76-84.

Riusxander, H. and Sumirat, E., 2013. Feasibility Study for Gas Power Plant Project in the city of Muara Enim . *Indonesian Journal of Business Administration*, *2*(10), p.68799.

Aggarwal, S.K., Saini, L.M. and Kumar, A., 2009. Short term price forecasting in deregulated electricity markets, *International Journal of Energy Sector Management*.

Anbazhagan, S. and Kumarappan, N., 2012. Day-ahead deregulated electricity market price forecasting using recurrent neural network. *IEEE Systems Journal*, *7*(4), pp.866-872.

Azadeh, A., Moghaddam, M., Mahdi, M. and Seyedmahmoudi, S.H., 2013. Optimum long-term electricity price forecasting in noisy and complex environments. *Energy Sources, Part B: Economics, Planning, and Policy*, *8*(3), pp.235-244.

Rangkuti, F., 1998. Analisis SWOT teknik membedah kasus bisnis [SWOT analysis techniques dissect business cases], Gramedia Pustaka Utama.

Kaminski, V., 2013. Energy markets. Risk Books.

Shahidehpour, M., Yamin, H. and Li, Z., 2003. *Market operations in electric power systems: forecasting, scheduling, and risk management*. John Wiley & Sons.

PT PLN (Persero), 2013. *Rencana Usaha Penyediaan tenaga Listrik PT PLN (Persero) 2013-2022* [Electricity Supply Business Plan of PT PLN (Persero) 2013-2022], Jakarta, PT PLN (Persero).

Dewan Energi Nasional Republik Indonesia, 2014. *Kebijakan Energi Nasional (KEN) Road Map Kebijakan Ketahanan dan Kemandirian Energi.* [National Energy Policy Road Map of Energy Security and Independence Policy] Available at: https://den.go.id/index.php/dinamispage/index/471-.html, Accessed on November 9, 2020.

Biographies

Nurhadi Siswanto is a faculty member and the Head of Department of Industrial and Systems Engineering at Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. He earned his bachelor degree in Industrial Engineering from Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, a master degree in Industrial Engineering from Purdue University, USA and a PhD from University of New South Wales, Canberra, Australia. His research interests include operation research, large-scale optimization, simulation and modeling of maritime transportation.

Firda Nur Rizkiani is a dual master student in Industrial and Systems Engineering at Institut Teknologi Sepuluh Nompember, Surabaya, Indonesia and Industrial Management at National Taiwan University of Science and Technology, Taipei, Taiwan. She earned her bachelor degree in Industrial Engineering from Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. When she was in undergraduate program, she was a laboratory assistant in Quantitative Modelling and Industrial Policy Analysis (QMIPA) Laboratory which is responsible in conducting various laboratory activities, assisting lecturers, and many more. In addition, she also has experience of being trainer in discrete event simulation software training held by QMIPA Laboratory of Industrial Engineering ITS for academics and practitioners. She is able to develop her research in operations research, optimization, and simulation modeling as a contribution to the academic fields.

Stefanus Eko Wiratno is a faculty member of Department of Industrial and Systems Engineering at Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. Currently, he is a doctoral student in Industrial Engineering of Institut Teknologi Sepuluh Nopember. He earned his bachelor degree in Industrial Engineering from Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, a master degree in Industrial Engineering from Institut Teknologi Bandung, Indonesia. His research interests include operation research, simulation and system modeling.