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Probabilistic Analysis on Levelized Unit Electricity Cost (LUEC) Calculation of Small Medium Reactor Nuclear Power Plant (SMR NPP) In Indonesia

Nuryanti, Suparman

Center for Nuclear Energy System - National Nuclear Energy Agency (BATAN), Jl. Kuningan Barat, Mampang Prapatan, Jakarta

Abstract

SMR NPP is an alternative to overcome the dependency to diesel power plant especially in outside Java Bali system. Economic analysis is a crucial thing that should be done prior to any investment decision on the SMR NPP project and generally done by calculation of Levelized Unit Electricity Cost (LUEC). NPP projects, include SMR, are vulnerable to a number of uncertainty variables. The goal of this study was to perform economic analysis of SMR NPP project with capacity 2 x 100 MWe in Indonesia by incorporating an amount of uncertainty variables, namely the probabilistic approach. The research method is calculating LUEC with deterministic approach followed by the probabilistic approach. Probabilistic approach is done by simulating the effect of uncertainty variable on LUEC using Monte Carlo simulation technique. The results show that the deterministic approach with a discount rate of 10% obtained LUEC at 12.87 cents US$/kWh. Whereas the probabilistic approach obtained LUEC of 13.10 plus minus 1.43 cents USD/kWh at a discount rate of 10% and amounted to 8.11 plus minus 0.88 cents USD/kWh at a discount rate of 5%. calculation in deterministic approach was 12.87 cents USD/kWh. While LUEC as the results of uncertainty variables simulation on probabilistic approach were 13.10 ± 1.43 cents USD/ kWh on discount rate 10% and 8.11 ± 0.88 cents USD/kWh on discount rate 5%. Occurrence probability of LUEC is less than 13 cents USD/kWh (benchmark value) was about 100% on discount rate of 5% and 50% on discount rate of 10%.

Keywords: Uncertainties, probabilistic analysis, LUEC, Monte Carlo technique, SMR NPP

Corresponding Author:
Nuryanti, Suparman,
email: nuryanti@batan.go.id

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1. Introduction

The main characteristics of the electricity system outside Java-Bali are: limited grid (isolated areas) and still dominated by diesel power plants. Currently there are 4,640 units existing power plant, approximately 4,368 units (94.14%) were diesel with an installed capacity reached to 36.94% of the total capacity [1]. Fuel price fluctuation as well as fuel supply chain up to the diesel location become a problem that lead to the high cost of electricity power generation in this region. Small Medium Reactor (SMR) could be an alternative to overcome the dependency of isolated areas to oil-fired power plants, because this reactor type was focused on the limited grid region [2,3]. The category of SMR encompasses the

designs below 700 MWe, but new design layout and concepts are made possible by smaller size (i.e., from 350 MWe downwards) [2, 4, 5]. SMRs competitiveness lies on the higher degree of innovation implemented in their designs, improvement of safety aspects, as well as the lower initial capital costs compared to the large ones (although the unit cost USD/kWe higher at SMR NPP) [3, 6].

Economic analysis of electricity generation projects, generally done by calculating Levelized Unit Electricity Cost (LUEC), was crucial to be done prior to any investment decision on the SMR NPP project [7]. NPP project (include SMRs) are vulnerable to a number of uncertainties. Therefore an approach which is able to accommodate the possibility of these uncertainties was needed, namely probabilistic analysis [8,9].

There are many studies related to probabilistic analysis on electricity generation project [3, 10, 11, 12, 13]. This study focused on the SMR with specificity of Indonesia condition (infrastructure obstacle, payroll standard referring to PT PLN (Persero), etc.) [14]. Therefore the purpose of this study was to analyze the economics of SMR project in Indonesia considering the possibility of uncertainties. Study was conducted on SMR NPP 2 x 100 MWe. In this study, LUEC calculation performed by the deterministic approach first and then followed by the probabilistic approach. Probabilistic approach was done by simulating the effect of uncertainty variables simultaneously to LUEC. The probabilistic analysis performed by the Monte Carlo simulation techniques. Monte Carlo simulation is preceded by the development of a deterministic model that maps set of input variables to a set of output variables with some equations.

2. Methodology

Levelized Unit Electricity Cost (LUEC)

LUEC is the constant unit cost (per kWh) of a payment stream that has the same present value as the total cost of building and operating a generating plant over its life [7]. Mathematically, the calculation of NPP LUEC expressed by equation (1) [18]:

$$LUEC = \frac{\sum_t \left(\frac{Investment_t + O\&M_t + Fuel_t + Decommisioning_t}{(1+r)^t}\right)}{\sum_t \left(\frac{Electricity_t}{(1+r)^t}\right)} \quad (1)$$

With:

$Electricity_t$: electricity production on year "t"
LUEC : Levelized Unit Electricity Cost
$Investment_t$: investment cost on year "t"
$O\&M_t$: Operation& maintenance cost on year "t"
$Fuel_t$: Nuclear fuel cost on year "t"
$Decommisioning_t$: Decommisioning cost on year "t"

Based on engineering economic principle, equation (1) shows that basically LUEC is the quotient between the sum of all cost component and the sum of electricity production which was discounted to present value [19].

Monte Carlo Simulation

Monte Carlo simulation is defined as a statistical sampling technique used to estimate the solutions of the quantitative problems [15]. Monte Carlo simulation is preceded by the development of a deterministic model that maps set of input variables to a set of output

variables with some equations. Furthermore, the deterministic model evaluated repeatedly with random numbers as input [16]. Repetition (iteration) is performed many times to ensure the robustness of the results [3, 17]. Because the evaluation was done repeatedly then there was an uncertainty propagationas the basic principle of Monte Carlo simulation [18]. Scheme of deterministic model and uncertainty propagation could be seen in Figure 1 and Figure 2.

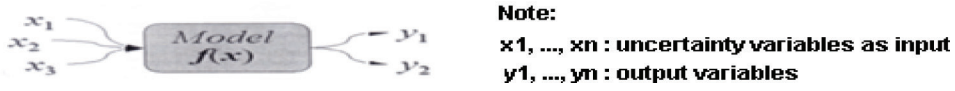

Figure 1: Deterministic Model [16].

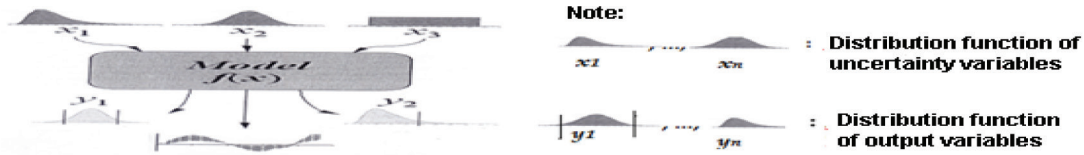

Figure 2: Uncertainty Propagation [16].

Steps of Study

The phases of study are as follows:
- Data gathering (technical and economic) that are required in the economic analysis
- Establish the necessary assumptions in the calculation
- Updating cost account data to the reference year (assumed in 2012)
- Calculating LUEC using deterministic models by using Mini G4ECONS, spreadsheet-based software from International Atomic Energy Agency (IAEA) [20].
- Distribution assignment of the uncertainty variables
- Simulating the uncertainty variables to the output (LUEC) by using @Risk [21].
- Analysis of the results and conclusion

3. Data and Assumptions

Technical and Economics Parameters of Reference NPP

Some techno-economic parameters of SMR NPP under study are shown at Table1.

Table 1: Techno-Economic Parameters of SMR NPP.

No	Parameters	Unit	Value
1	Capacity	MW	2 x 100
2	Capacity Factors	%	93[22]
3	Annually power production	MWh	1,629,360,000
4	Burn Up	MWd per metric tonne U_{235}	60,000
5	*Discount rate*	%	10
6	Construction time	Year	5
7	Project lifetime	Year	40
8	Exchange rate	Rp per USD	12,000,-[23]
9	interest rate	%	3.27[24]