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Decision Area of Distributed Generation Investment as Deferral Option in Industrial Distribution System Using Real Option Valuation

Yusra Sabri[1], Pradita Octoviandiningrum Hadi[2], and Nanang Hariyanto[3]

School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Indonesia
[1]yusra@power.ee.itb.ac.id, [2]praditahadi@ymail.com, [3]nanang.hariyanto@stei.itb.ac.id

Abstract: Distribution system planning (DSP) aims to ensure, that the electricity distribution can satisfy the demand in an optimum way. It has to provide the necessary economical, reliable, and secure electricity to consumer. Network solutions of DSP are the solutions that need adding and/or replacing some network asset. Traditional response is a large investment that creates large capacity. Therefore there may be unused capacity for period years. Thus, there is excess system capacity after the investment is made. In other hand, the alternative responses frequently install distributed generation in very small size. Original plan can be deferred by installing distributed generation. Investment using distributed generation is an option to defer the larger investment in distribution planning. Utility can use this option to face the uncertainty in demand projection. This paper proposes model for determining decision area of distributed generation investment as deferral option in industrial distribution system planning. It uses real option valuation to define the boundary by using the critical value. This study depicts the decision area by 'discount rate'- 'electricity price on transmission' and 'discount rate' -'delaying time' boundary.

Keywords: distribution system planning**,** load forecasting**,** decision area, deferral decision, distributed generation, distribution planning, real option valuation.

1. Introduction

The industrial development will make an expansion of industrial area. There is also giving a possibility of arise of the new industrial area. It means the increasing electricity demand can occur at existing load centers or appear as new load centers. However, it has an uncertainty because the growth of the electricity cannot be expected, when and how big the new demand should be added or how much the future generation cost is. The utility can fulfill the increasing demand by expanding the electrical distribution network through transmission system. This option requires a big amount of investment. There is a risk if the increasing demand is below the predicted one. Because the utility could cause a big amount of investment, but get low pay-off. In other way, utility can meet the demand by installing distributed generation (DG). It can be fossil-fuelled or using renewable energy as primary source. Deferring transmission and distribution network reinforcement is one of DG benefits [1]. To face the uncertainty, the utility can use the investment decisions with Distributed Generation (DG). Installing the DG can defer the large investment [2,3]. Utility has an obligation to choose which way that is more profitable and reliable [4]. It depends on the current condition. Therefore, determining the critical condition can help the utility to use its obligation to choose the way of investment.

2. Problems Description

Many things can influence the decision-making of investment. They include electricity demand growth, possibility of adding new big demand, investment cost of transmission line and distributed generation, primary energy prices, current discount rate, electricity-selling price, possible delaying time, and many others. Each parameter can give different impression for utility in making the decision of investment. It is also possible that each parameter has any relations with other parameter in providing the impression.

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Defining the decision area by parameters boundary can help utility to use its right to choose the way of investment. The Utility could see the position of its current condition and realize in which area it is located. The problems are:

a. How the utility gets the boundary parameters on determining the decision area to choose the way of investment for supplying the industrial demands?
b. What is the effect of the parameter variation to the boundary area?

More parameters included will make the dimension of boundary area more complex. It is necessary to restrict the used parameters for better impression. This study use two parameters for making the boundary of decision area in order gaining better impression. They are possibility in delaying time versus discount rate and primary energy prices as electricity price on transmission versus discount rate, another parameters are assumed to be constant.

3. Boundary of Real Option Valuation in DSP

Distribution system planning (DSP) aims to ensure the electricity distribution can satisfy the demand in an optimum way. It has to provide the necessary economical, reliable, and secure electricity to consumer [5,6]. DSP is an optimization process to acquire a number of design variables, such as size and location of substation, number of feeders and their routes, number also the location of the sectionalizing switches, radial or meshed network structure, etc. The optimal values can be determined by optimizing multiple objectives, such as minimize the installation cost of new facilities, capacity up-gradation of the existing facilities, the operational cost, and maximize the system of reliability [6]. Investment decisions leads to strategic and financial goals. They can follow the different path but still point to the same direction. They usually come in incremental steps. The real option at each step in the decision-making process is untied based on the examination of additional information. An investment decisions is rarely a now-or-never decision.

In the real option framework, utility will have the option to expand network once the demands growth well, taking full advantage of the upside potential. Otherwise, if the demands collapse after competitive entry, utility may want to sell the asset and cash the salvage value. Both cost and revenues are flexible and adjust to the information as it arrives. The options value the creation and risk mitigation through managerial flexibility.

An option is a right, but not an obligation. A **CALL** option gives the owner the right to buy the underlying asset at a predetermined price on or by certain date. A **PUT** option gives the owner the right to sell the asset at a predetermined price on or by certain date [4].

Value of the CALL option is the difference between today's value of the expected future payoff S and the cost K of exercising the option of maturity. The expected future payoff S is the value of the asset that owner will acquire by exercising the option. The value of the PUT option by analogy is the difference between the cost K of acquiring the asset and the price at which owner can sell the underlying asset at maturity. Equation below gives the mathematical formula for the value of a CALL and a PUT.

$$CALL = Max[0, S - K] \tag{1}$$

$$PUT = Max[0, K - S] \tag{2}$$

If the asset value **S** drops below the cost **K**, the call option value remains zero, and the owner of the option will not exercise the option. If the value of the asset **S** becomes greater than the exercise price **K**, the put option goes out of the money and its value diminishes. In other words, an option with a negative payoff will expire unexercised.

4. Model Description

This section depicts the description of proposed model for determining decision area of distributed generation investment. The expansion investment decisions approach consists of four steps. They are forecasting demand, setting expansion variants, technical and cost analysis, and determining area of decision-making. Figure 1 shows the general flowchart of the approach.

We may divide the decision approach into two parts: the preparation and determination of decision area approach. In the preparation, the planner should forecast the demands and set expansion variant to face the future demands. By using the generated expansion variants in the previous stage, doing technical and cost analysis that includes power flow and revenue-cost calculation. The final stage uses the result analysis for getting the critical value of option value. Finally, it will generate the decision area of investment.

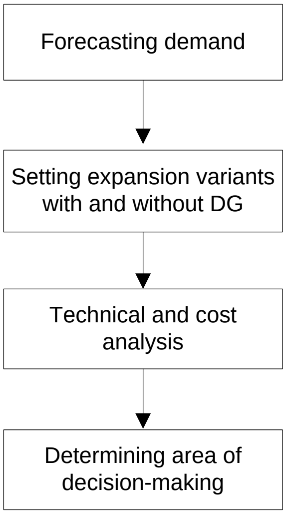

Figure 1. Flowchart of decision approach

A. Demand Forecast

The electricity demand would grow continuously through the time. By using demand forecast, the planner can project the future demands. The demand forecast is one of factors affecting the planning process. It is important for planning engineer and economist to plan the future system expansion, such as type and size of generation plants, distribution, and transmission lines [7]. In this study, long-term demand forecast is used instead of to plan the system expansion.

Demand growth is not constant. It could be vary along the time. The geometric Brownian-motion-processes can describe the behaviour of demand growth over time [2]. By perform 'M' times of Monte Carlo simulations for analysis period "T", the planner could forecast the future demand using (3) and (4).

$$\Delta P_{i,t} = \mu \cdot P_{i,t-1} \cdot \Delta t + \sigma \cdot \varepsilon \cdot \sqrt{\Delta t} \qquad (3)$$

$$\sum_{i=1}^{M} \sum_{t=1}^{T} P_{i,t} = P_{i,t-1} + \Delta P_{i,t}$$

Where:

$P_{i,t}$ = Load at time t

μ = Demand annual growth rate.

$\Delta t =$ Interval of time

$\varepsilon =$ Normally distributed random variable N (0,1)

$\sigma =$ Standard deviation.

B. Setting Expansion Variant

B.1 Base Plan

Base plan is an expansion plan with network solutions for facing the future demands. In this study, it includes the installing of new transformer and building the transmission line. For the ease of analysis, it assumes to be only one expansion variant in the base plan. The rating of transformer refers to the commonly used by utility. The investment cost of the transmission line includes the acquittal cost of used area.

B.2 DG Plan

DG plan is an expansion with non-network solutions. It is installing DG in the first year for deferring the base plan. DG option will be vary. It can be plants with renewable energy resources or fossil-fuelled or the combination of them. For better impression, this study limits the DG option to fossil-fuelled plants, diesel and gas internal combustion engine (ICE). These technologies are primarily chosen for their wide dissemination across the world, their lower installation costs, their commercial availability, and the relative easiness with their location. In addition, they are also chosen because they can provide incremental peaking capacity and could enhance local area reliability and power quality [2]. The expansion variants consist of gas ICE, diesel ICE, or combination of gas and diesel ICE.

C. Technical and Cost Analysis

Technical analysis means doing power flow analysis of the system model for acquiring the economic dispatch of the generation either from centered power plant then transfer using transmission line or from DG plants, which are installed near the load point. Cost analysis means calculate the operation cost for supplying the demands.

In this stage, the planners do optimal power flow using MATPOWER 4.1 [9]. It will result the generation cost of all system in USD/hour. It simulates the system in one value of demand. For getting the all costs that have to be paid, the result must be multiplied by all the operation time for supplying the demand, 8760 hours in a year. Then the annual cost can be obtained. In line with that stage, the pay-off is also calculated using MATLAB R2009a. So in the end of this stage, the annual cost and pay-off can be obtained and ready for going to the next stage.

D. Determining Area of Decision-making

The risk of uncertain demand can change the large investment such as build the transmission line and expand the distribution substation to the lower investment option. Installing DG can be an option of the lower investment. Investment with DG is an investment decision for delaying the large investment, which is building transmission line and expanding the distribution substation (investment without DG). For choosing the option, the planner should know the value of the option. The planner could choose the option with better value. However, the planner has the right to choose for picking out the option or not. It would depend on the readiness of the utility for facing the risk of the option.

In this case, the option is to defer the large investment by installing DG plant first. Equation (5) shows the Option Value (OV) that is the difference between the net present value of project with and without DG. This value is also can be seen as defer value.

$$OV = E(NPV_{withDG}) - E(NPV_{withoutDG}) \quad (5)$$

The objective function is making the option value being equal to zero. It will provide the critical value as a boundary of decision area. The value of cash flow is discounted by discount rate 'r'. It is called as net present value (NPV). The cash flow (CF) is calculated according to (8) and (9).

$$Objective\ Function: OV = 0 \quad (6)$$

$$NPV_i = \sum_{t=1}^{T} CF_{i,t} \cdot (1+r)^{-t} \quad (7)$$

$$CF_{i,t} = Incomes_{i,t} - TotalCost_{i,t} \quad (8)$$

$$TotalCost_{i,t} = InvestmentCost_{i,t} + OperationCost_{i,t} \quad (9)$$

Figure 2 shows the flowchart of determining the area of decision making.

5. Numerical Analysis

A. Study Case

This study case presents the new industrial area with the predicted load that utility should supply. The distribution network is radial. Figure 3 describes the distribution network under study. It is a 20 kV three-phase balanced network.

Table 1 presents the peak of each load point in the first year. The demands grow with 4.5% annual growth rate and 1.5% standard deviation.

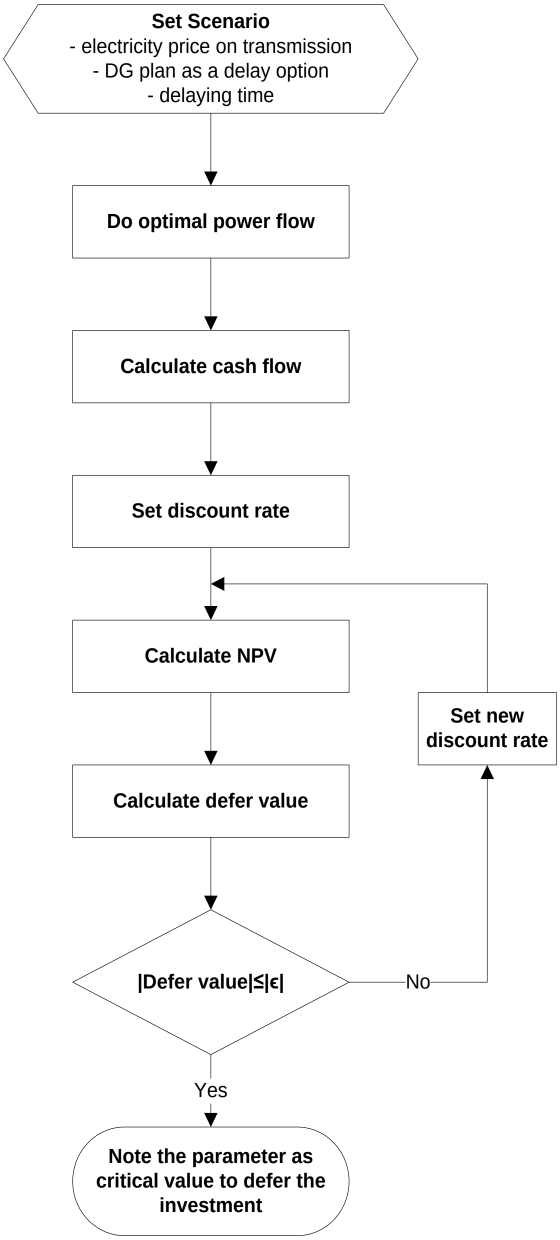

Figure 2. Flowchart of determining the area of decision-making

Power demand is using the discrete load steps in each year that consists of peak, medium, and minimum load. Figure 4 shows the details of load duration curve. This study assumes cos φ equals to 0.85.

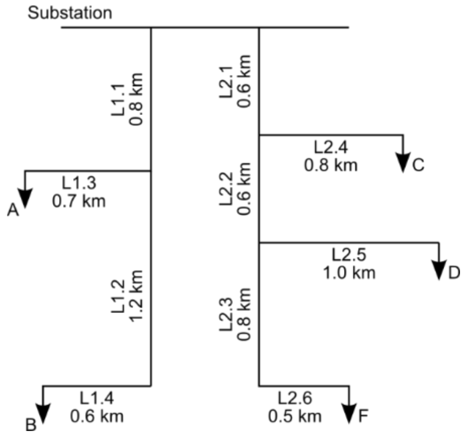

Figure 3. Diagram of the distribution network under study

Table 1. Load Point

Load Point	Peak MW
A	0.66
B	0.96
C	0.80
D	0.72
E	0.56
TOTAL	**3.70**

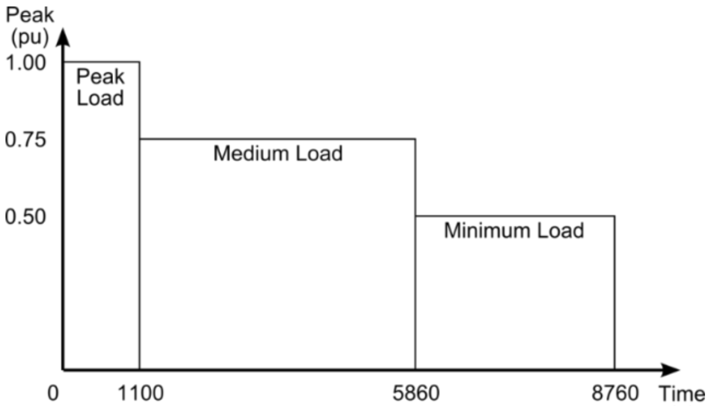

Figure 4. Load duration curve

The design of the overhead lines for supplying the next ten years' demands, shown at Table 2. The conventional plan for supplying the demands is building a transmission line between main substation and the new substation and installing a 30 MVA power transformer. The cost of this investment is 3.8 million USD. There is a possibility for changing the plan by installing the distributed generation (DG) instead of a power transformer and transmission line.

Table 2. Data of Overhead Lines

Line	Conductor Type	Length
		Km
1.1, 2.3	AAAC 150 mm^2	0.8
1.2	AAAC 150 mm^2	1.2
2.1, 2.2	AAAC 150 mm^2	0.6
1.3	AAAC 70 mm^2	0.7
1.4	AAAC 70 mm^2	0.6
2.4, 2.6	AAAC 70 mm^2	0.8
2.5	AAAC 70 mm^2	1.0

B. Simulation result

The stochastic modeling of demand projection is using Monte Carlo simulation with 1000 number of iterations. The analysis period is 10 years with annual sub-period. Figure 5presents the 20 results of the first-iteration.

Table 3 The Result of Total Peak Demand Projections shows further detail about the result of total peak demand projections. The wider of projections band shows that the larger number of years makes the demand projections uncertainty.

For setting the expansion variants with deferral option, this study uses two types of DG: Gas ICE 3 MW and Diesel ICE 3 MW. The investment cost of Gas ICE 3 MW is 500 USD/kW and the investment cost of Diesel ICE 3 MW is 430 USD/kW. The generation cost is 89 USD/MWh for Gas and 208 USD/MWh for Diesel.

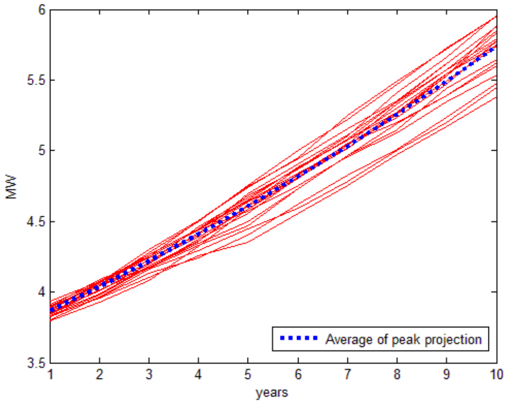

Figure 5. Total demands projection using stochastic processes (the 20 result of first-iteration)

Each plan can defer the large investment 9 years in maximum.

Table 3. The Result of Total Peak Demand Projections

Year	**Min (MW)**	**Average (MW)**	**Max (MW)**	**Standard Deviation**
1	3.74	3.87	3.98	0.90%
2	3.88	4.04	4.23	1.25%
3	4.03	4.22	4.40	1.49%
4	4.21	4.41	4.64	1.66%
5	4.35	4.61	4.86	1.81%
6	4.55	4.82	5.12	1.91%
7	4.74	5.03	5.39	2.00%
8	4.94	5.26	5.67	2.11%
9	5.15	5.50	5.93	2.22%
10	5.36	5.74	6.20	2.28%

There are three expansion variants for deferring the large investment. They are:
a. DG plan 1: Two units of Gas ICE 3 MW
b. DG plan 2: One unit of Gas ICE 3 MW and one unit of Diesel ICE 3 MW
c. DG plan 3: Two units of Diesel ICE 3 MW

Each deferral planning consists of two plans: base plan and DG plan. Base plan is a planning in expanding the network by building the transmission line and install transformer. DG plan is a planning with installing DG as an option to defer the larger investment.

There are three deferral plans in this study. The deferral planning 1 consists of base plan and DG plan 1 as an option to defer the base plan. The deferral planning 2 uses DG plan 2 as an option to defer base plan. In line with previous deferral plan, the deferral planning 3 uses DG plan 3 as an option to defer.

The critical values to deferincrease with the decreasing of delaying time (Figure 6). The shorter delaying time creates the higher critical value to defer. The shorter delay time makes the shifting of critical value is getting larger. The critical value is a linear function of electricity price on transmission.

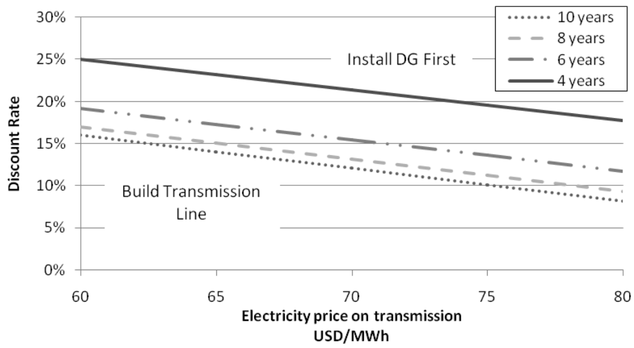

Figure 6. Critical value to defer for delaying time variations - deferral plan 1

The variation of electricity price on transmission also gives variation in critical value to defer (Figure 7). The shifting of the critical value is equivalent to the interval of electricity price on transmission. The higher electricity price on transmission gives the lower critical value of the discount rate in the same delay time. The longer delaying time decrease the critical value to defer. It is very significant in the early year, but less sloping in the longer delay time. It seems that the critical value is an exponential function of delaying time.

All critical value of three deferral plans decrease by the increasing of electricity price on transmission. All of them are linear functions of electricity price on transmission. Figure 8 depicts the decision area of investment by 10-years delaying time of large investment. Each deferral plan has different wide of decision area. The deferral planning 1 has the tightest decision area, whilst the deferral planning 2 has the widest decision area. However, if we neglect the almost impossible value of discount rate, the deferral planning 3 will never get chosen. Besides, the condition must have high discount rate and the high electricity price on transmission in order to the planner can choose the deferral planning 2.

All critical value of three deferral plans decrease by the increasing of delaying time of large investment. All of them are exponential functions of electricity price on transmission. Figure 9 depicts the decision area of investment by 80 USD/MWh of electricity price on transmission. Like the deferral case before, each deferral plan in this case has different wide of decision area. The deferral planning 1 has the tightest decision area, whilst the deferral planning 2 has the widest decision area. However, if we neglect the almost impossible value of discount rate, the deferral planning 3 will never get chosen. Besides, the condition must have high discount rate and long delaying time in order to the planner can choose the deferral planning 2.

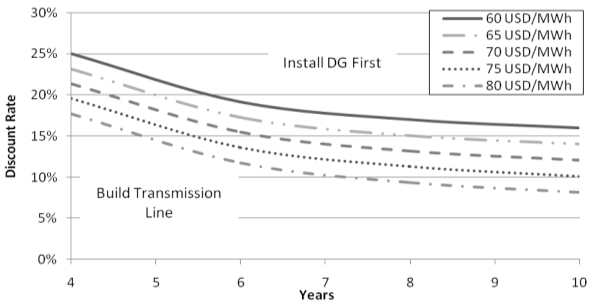

Figure 7. Critical value to defer in electricity price on transmission variations - deferral plan 1

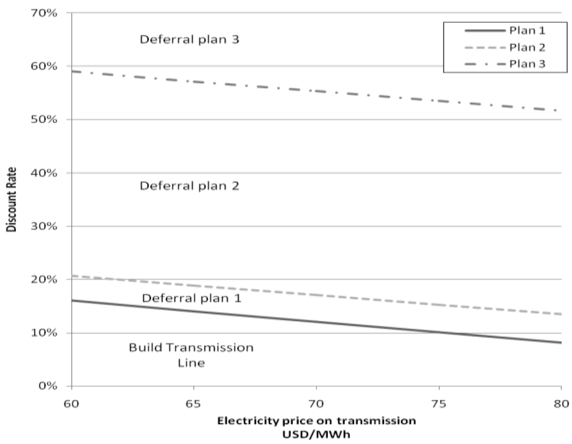

Figure 8. Decision area of investment by 10-years delaying large investment

The one price of electricity price along the study period causes the critical value's linear functions of electricity price on transmission. NPV exponentially calculated the cash flow discount by years. It causes the critical value's exponential functions of delaying time of large investment.

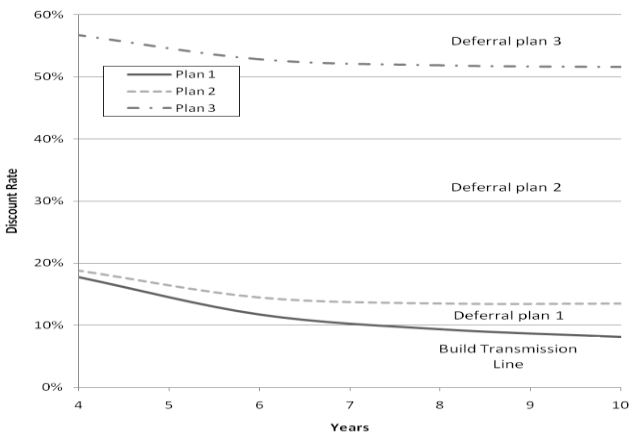

Figure 9. Decision area of investment by 80 USD/MWh of electricity price on transmission

6. Conclusions

This works develops a model for determining decision area of distributed generation investment in industrial distribution system. We can use the discount rate as a function of the delaying time of the large investment or the electricity price on transmission as a boundary of decision area of investment.

The boundary of decision area can be varied depends on the delaying time of the large investment and the DG generation cost. The shorter delaying time makes the lower electricity price on transmission has to available on the same value of discount rate. The higher DG generation cost creates the higher boundary of electricity price on transmission for the same value of discount rate.

The results of the conducted study show that the model can create the decision area of investment. For developing the model, the further studies can be conducted. They include (but not limited to):

1. Conduct the study with more varied DG plan, such as in variant and power rating.
2. Conduct the study with more parameter for determining the decision-area, such as the possibility of adding new big demand, the investment cost variation of transmission line and distributed generation.

Nomenclature

A. Acronyms

DG	= Distributed Generation
DSP	= Distribution System Planning
ICE	= Internal Combustion Engine

B. Variables

CALL	= Value of call option
CF	= Cash Flow
K	= Exercise price
M	= Number of Monte Carlo simulations
NPV	= Net Present Value
OV	= Option Value
P	= Peak Demand
PUT	= Value of put option
r	= Discount rate
S	= Asset value
T	= Study period (in years)
ΔP	= Change of peak demand from the previous sub-period
Δt	= Period change of time
μ	= Demand growth
σ	= Standard deviation
ε	= Normally random number (N(0,1))

C. Indices

i	= Monte Carlo simulation
t	= Sub-period of time (annual)

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Yusra Sabri received his Sarjana (Bachelor) degree in Electrical Engineering from Institut Teknologi Bandung (ITB), Indonesia 1976 and his Dipl.Ing, DEA and DR.Ing degrees in Electrical Power Engineering from Institut National Polytechnique de Toulouse, France in 1977, 1978 and 1981 respectively. He is currently working as lecturer in The School of Electrical Engineering and Informatics ITB. His research interests are in Power and Distribution System Planning.

Pradita Octoviandiningrum Hadi was born in Ambon, Indonesia, in 1990. She received the B.Sc (2012) and M.Sc (2014) degrees in electrical engineering from Bandung Institute of Technology (ITB), Indonesia. Currently she is a Ph.D student in Shibaura Institute of Technology (SIT), Japan. Her research interests include distributed generation, renewable energy, and dc system.

Nanang Hariyanto was born in Jember, Jawa Timur, Indonesia, on July 26, 1962. He graduated from the Electrical Engineering Department, Bandung Institute of Technology. His employment experience included Synatech Industry, and as a researcher at Power System Laboratory, ITB Indonesia. His special fields of interest included power system planning and dynamic stability.