Electric Power Generation Optimization With Markowitz Model

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Abstract: Factors of economic growth, the growth of the population and the global warming issue require that electricity providers must be able to provide electrical power energy with a high-reliability factor. The duration of extinguishing and how often blackouts are a measure of the reliability of an electric power system. Diversification of the types and sources of electrical energy as a way to ensure the availability of electrical energy in the form of parallel work of power generation systems. The existence of a variety of constraints on each generation system so that a special method is needed to be able to regulate the operation variation/scheduling to provide electricity for consumers. This journal discusses the optimization method of the portfolio of electric energy generation systems using the Markowitz model. This model provides an optimum value for the variation of the power plant system at each time indicated by an efficient frontier curve. Every optimum combination of plants that might be on the frontier efficient curve line.

1 INTRODUCTION

Diversification is the act of spreading investment into several forms of investment projects and if it is appropriate to choose the characteristics of each project, the effects of the portfolio will reduce the overall risk. (Acemoglu,1997)
This portfolio is essentially a combination or combination or set of assets / projects, both in the form of real assets and financial assets owned by companies / investors, formed to reduce risk. Markowitz, 1952 and Bodie, 2009).

In the process of forming this portfolio must go through an investment process consisting of a policy determination process, investment analysis, portfolio formation, portfolio performance evaluation, and portfolio revision process.(Chandra, 2017)

At least there are two things that underlie this: first if one is wrong in planning and decision making will have severe and long consequences for the company, considering the number of funds spent is quite large and tied for a long time, and secondly if there is wrong in estimating their needs, for example, investment is too large (over investment) there will be burdens which should not be necessary. Conversely, if the investment is too small (under investment) the company will lack production capacity. (Sovic, 2016; Brook, 2016; Hult, 2017)

From the description above shows how important the management process is to risk, its relationship with how to avoid, prevent and reduce or in other words the process of maximizing opportunities and minimizing failure. For this reason, it is very necessary to seek, build, implement realistic best strategies, and allocate limited resources into the most productive areas. This is a very challenging task for executives of any company in any industry and even more challenging for executives who manage business portfolios.
Electricity generation nowadays presents a greater number of challenges related to reliability, sustainability and security of supply. The use of renewable resources in power generation has been adopted in most OECD (Organization for Economic Cooperation and Development) countries as an answer to the climate change problems originated by the burning of fossil fuels in the traditional thermal plants to supply the ongoing increase in electricity demand. (Eusébio et al., 2015).
In terms of the economic model, the electricity industry has evolved from a vertically integrated state-owned monopoly company (not subjected to the

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normal rules of competition) to a liberalized market where generators and consumers have the opportunity to freely negotiate the purchase and sale of electricity. Usually the liberalization of the electricity market allows entry of independent power producers with long term contracts and the creation of active wholesale and retail markets came in a later stage. Nowadays the actual economic situation affects all the participants in the sector, consumers, producers and "prosumers", many hypotheses to decrease the bill to pay for electricity are considered, such as different energy suppliers, control load programs, load forecasting, smart-grid, smart-metering and smart-box.

In terms of the economic model, the electricity industry has evolved from a vertically integrated state-owned monopoly company (not subjected to the normal rules of competition) to a liberalized market where generators and consumers have the opportunity to freely negotiate the purchase and sale of electricity.

The energy sector is in transition to a flexible and sustainable energy system based on renewable energy sources. This complex transition is affecting multiple levels in the sociotechnical system. One driver of the transition is climate change that enforces the policy push from the macro level to change the way energy is produced, delivered, and used. As part of the energy system evolution, the role of the end user in the energy sector is undergoing profound changes, and consumers are increasingly being empowered to participate actively in the production and use of energy. (mesaric et all, 2017: Kotilainen, 2018)

The small passive consumer evolves to an active player, participating in the generation of electricity and the provision of network services. In this context, both aggregators and companies can bring their customers, consumers, producers, consumers and traders to market (Lampropoulos et al., 2010) (Stern, 1999)

With the new paradigm of the distributed generation of electrical models allows the medium, small consumers and producers to integrate the satisfaction of the power system because they adopted opposed to the traditional power system, composed by medium and large power plants. (Markovis, 2013)

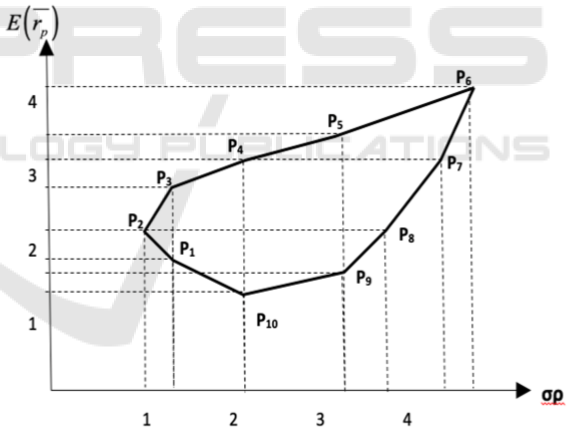
The optimization method of the portfolio of electric energy generation systems using the Markowitz model is the main objective in this research.

2 METHOD

This research is a descriptive research which describes the determination of the optimal Portfolio model with the Markowitz model chosen from the many efficient portfolio alternatives that can provide a certain level of return in accordance with the risk dared to be borne by the manager, the optimal combination is shown on Markowitz's efficient curve. Figure 1 shows the efficient curve where P1 until P10 are possible portfolio combinations, Markowitz states that efficient frontiers are all efficient portfolios that may be from a combination of risk and return P2, P3, P4, P5, P6. According to Markowitz (Xu et al, 2017), the key why investors / companies only need to look at some portfolios is located in the efficient set theorem, which states that (Sharpe *et al,* 2005):

Manager will choose an optimal portfolio from a number of portfolios that: 1) Offering maximum expected return for various levels of risk and 2) Offer minimum risk for various levels of expected return.

Figure 1: Markowitz efficiency curve



Concept of Expected Value is one method of how we

Figure 1: Markowitz efficiency curve

combine probability quantitatively with investment opportunities, while the risk in an investment project is shown by the size of the expected rate of return that deviates from the actual rate of return where the greater the deviation means the higher the level of risk. Standard deviation (SD) as a measurement of the variability of distribution based on this statistical science. The optimal Portfolio model with the Markowitz model chosen from the many efficient portfolio alternatives that can provide a certain level of return in accordance with the risk dared to be borne by the manager, the optimal combination is shown on Markowitz's efficient curve (Halim, 1995; Jogiyanto, 2003).

$$\sigma = \sqrt{\sum_{i=1}^{n}[(CF)x_i - EVCF]^2 P(x_i)}$$

$$\sigma^2 = \sum_{i=1}^{n}[(CF)x_i - EVCF]^2 P(x_i) \quad (1)$$

where ; σ = Deviation standard;σ^2 =Varians; (CF)xi= Cash flows obtained in the case of i; EVCF=Expected value of cash flow; P(xi)= The probability of the occurrence of cash flows in conditions i and ; n =Frequency of cash flows received.

According to Markowitz the expected return of a project portfolio is a weighted average of expected returns for each individual project (Gao, 2003) so that the expected value of a project portfolio is;

$$E\left(\bar{r_p}\right) = E_p = \sum_{i=1}^{N} X_i E\left(\bar{r}_i\right) \quad (2)$$

With Xi expressed as;

$$X_i = \frac{\textit{Funds investested in the project}}{\text{Total Invsetment Fund in Portofolio}} \quad (3)$$

Where: $E\left(\bar{r_p}\right)$= Expected portfolio return from the project; Xi = Proportion of funds invested in the project I; $E\left(\bar{r}_i\right)$= Returns expected from the project I; N=Returns expected from the project i.

Whereas to calculate the standard deviation (standard deviation) the Markowitz model portfolio consisting of N projects includes multiple addition actions shown in equation (2) to N projects.

$$\sigma_P = SD_P = \sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} X_i X_j \sigma_{ij}} \quad (4)$$

if there are three projects in the portfolio, then the portfolio risk equation (2) will become;

$$\sigma_P = SD_P = \sqrt{\sum_{i=1}^{3}\sum_{j=1}^{3} X_i X_j \sigma_{ij}}$$

$$= \sqrt{\begin{aligned}&[X_1^2\sigma_1^2 + X_1X_2\sigma_{12} + X_1X_3\sigma_{13} + \\ &X_2X_1\sigma_{21} + X_2^2\sigma_2^2 + X_2X_3\sigma_{23} + \\ &X_3X_1\sigma_{31} + X_3X_2\sigma_{32} + X_3^2\sigma_3^2\ ]\end{aligned}} \quad (5)$$

with $\sigma_{ij} = \sigma_i \sigma_j \rho_{ij}$

and portofolio varian $V_P = \sum_{i=1}^{N}\sum_{j=1}^{N} X_i X_j \sigma_{ij}$

where ; σ_P = Portfolio deviation; X_i, X_j= Proportion of funds invested in i & j projects; σ_i, σ_j=Standard deviation of projects i and j;
ρ_i, ρ_j = Coefficient of correlation between two random variables; σ_{ij}= Return covariance between two random variables i and j.

3 RESULTS AND DISCUSSION

Table 1 shows examples of Expected Monetary Value (EMV), standard deviations and covariance for each generation system or customer variation.

Nowadays there are various kinds of energy sources that are trying to be used to ensure the availability of electricity that tends to change, such as gas, wind, coal, oil, biomass, sunlight and much more. Each generation system has its own character, starting from investment, the size of the energy potential, risk to the environment, environmental conditions that can interfere with normal operation, operating costs, to the load variation. (Calvo, 2017). To reach these goals they research and develop new technologies which could better meet the needs of their consumers and to adjust to changes in the energy industry. The intense changes in worldwide energy industry are the results of a number of factors, such as the increase in energy demand, growing industrialization processes, and resources limitations. Many countries and energy providers are obligated to reconstruct their power generation mix and to develop new possibilities for producing energy. One reason is that their existing power plants are often old, not very energy-efficient and not very eco-friendly (e.g. featuring high CO2 emissions). Moreover, present energy utilities are heavily involved to develop CO2-free or CO2-low technologies. The construction of power portfolios is a process where energy utilities have to consider a number of factors and goals, including the following: minimizing the impact on the environment, keeping the cost of generation as low as possible and, from a power supplier's point of view, achieving the best profit for a given risk level. (Madlener).

EMV of an outcome is a combination of profitability and risk measure (with numerical probability) that adjusts to the value. In other words EMV is the result of multiplication between the probability of the outcome and the conditional value received if the outcome occurs; Standard deviation is a statistical value that is used to determine how the data is distributed in the sample, and how close the individual data points are to the mean or average sample value; and Covariance is a statistical measure of the relationship between two random variables. (Moore, 1983).

Table 1 shows examples of Expected Monetary Value, standard deviations and covariance for each generation system or customer variation.

Based on Table 1, it can be seen that 3 (three) systems of dissemination may be developed, namely the optimal project portfolio selected "CDH", so that the company will be faced with the problem of funding the project / determining the capacity of the power to be raised, ie how many parts / variations of money will be place it in each plant in the "CDH" project portfolio.

Using the Markowitz theory, the problem can be solved by forming a portfolio distribution that consists of variations in investment weights for each project which will also provide an expected portfolio return and standard portfolio deviation (a variety of efficient set theorems. For the case of the "CDH" project portfolio, A curve can be made attainable set or feasible set or possible combination of "CDH" portfolios as shown in Figure 24, which consists of 1000 portfolio combinations of the project "CDH" with a fraction / weight of each particular project (although basically this number of attainable sets can not countless or more than 1000 variations)

Table 1: Expected Monetary Value Standard deviation and Covariance, (Ticoh, 2012)

Power Pant	EMV (US$)	SD	COV(%)
C	5.889.036	13.432.690,11	228
D	11.234.202	17.703.410,90	157
H	31.666.278	62.470.393,51	197
CDH	16.297.952,20	21.532.936,78	132

by using Matlab software optimizer (listening program in Appendix 6). Calculation of each possible portfolio combination (attainable set portfolio) in Appendix 7 using equation (1) to (5) each portfolio standard deviation and expected portfolio return can be obtained

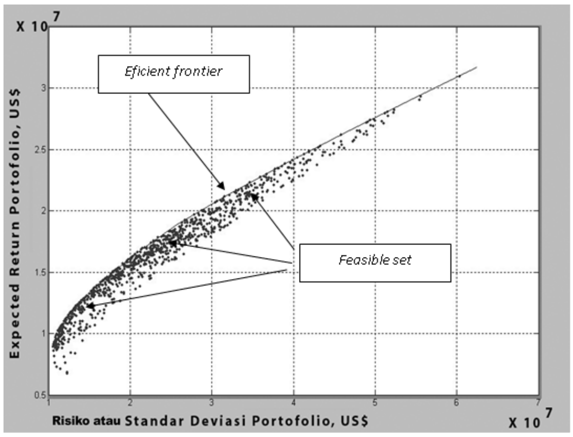


Figure 2: Curve combination of 1000 feasible sets of project portfolio "CDH" by using the help of Optimizer Matlab .

So that from this efficient frontier theorem (figure 1), a number of portfolios that meet both conditions are expressed as efficient set or efficient frontier, in which efficient portfolios are located, and according to Markowitz the combination under the curve can be ignored. Based on this, the portfolio is at the efficient frontier for the "CDH" project portfolio.

Below is listening program with matlab to produce 1000 combinations of 3 projects “CDH”.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Filename JanneD_Ticoh.M

% OPTIMALISASI PORTOFOLIO " ":

% Plotting an Efficient Frontier

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%

% Specify the expected returns, standard deviations, and

% correlation matrix for a hypothetical 3-asset portfolio.

%

returns = [5902995 11252120 31700830];

STDs = [13425504.28 17698112.37 62454711.32];

correlations = [ 1  0  0
                 0  1  0
```

```
0 0 1 ];%
% Convert the standard deviations and correlation
% matrix into a variance-covariance matrix.
% covariances = corr2cov(STDs , correlations);
%
% Compute and plot the efficient frontier for
% 100 portfolios along the frontier.
%
portopt(returns , covariances , 20)
%
% Randomly generate the asset weights for 1000
% portfolios starting from the MATLAB initial state.
%
rand('state' , 0)
weights = rand(1000 , 3);
%
% Normalize the weights of each portfolio so that the sum = 1.
%
total = sum(weights , 2);
total = total(:,ones(3,1));
weights = weights./total;
%
% Compute the expected return and risk of each portfolio.
%

[portRisk , portReturn] = portstats(returns , covariances , weights);
%
% Now plot the returns and risks of each portfolio
% on top of the existing efficient frontier for comparison.
%
hold on
plot (portRisk , portReturn , '.r')
title('Mean-Variance Efficient Frontier and Random Portfolios')
hold off
```

If the company has an investment policy to fund all projects in the "CDH" portfolio, then the portfolio for the company lies in the "p" point in Figure 3 clicked from Figure 2. This "CDH" portfolio has the expected value and a standard deviation of US $ 16,297,952.20 and US $ 21,532,936.78 .

According to the efficient frontier theorem, it is inappropriate to choose a portfolio that is not at the efficient frontier or in other words the portfolio is not included in an efficient portfolio. This is clear because when compared with the "CDH" portfolio which is at the frontier efficient frontier around the point "o" and "q" is more efficient than the portfolio at the point "p".

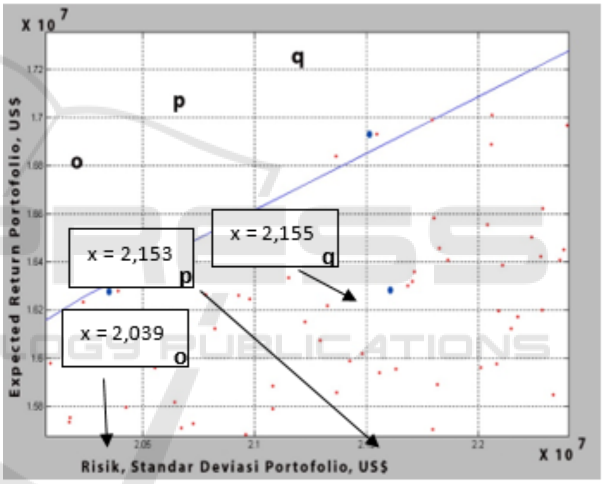


Figure 3: Location of the "CDH" project portfolio in the sample of 1000 portfolio combinations in Figure 2. If the company decides to fund the three projects in its overall portfolio "CDH"

Table 2: Comparison of the "CDH" portfolio if the company decides to fund the entire project and "CDH" portfolio that is at the efficient frontier if the company wants to fund a project with a certain weight

Porto folio	Project weight			Portofolio Risk	Portofolio Return	COV (%)
	C	D	H			
“o”	0,118	0,6054	0,2766	20.390.176,19	16.277.380,26	125
“p”	0,28	0,4	0,32	21.532.936,78	16.297.952,20	132
“q”	0,0074	0,7129	0,2797	21.547.188,01	16.931.232,28	127

Based on this analysis, then to get an optimal portfolio, the company must choose one of the optimal portfolios from a number of portfolios that are in figure 4 efficient frontier. This is very important for the company because if the company has limited investment funds, then the company can make the policy to invest funds with optimal variation and can provide opportunities for parties from outside the company to invest in each project in the "CDH" portfolio. According to the efficient set theorem, companies can choose the optimal portfolio "CDH" that is located along the efficient frontier, depending on how the company prefers risk.

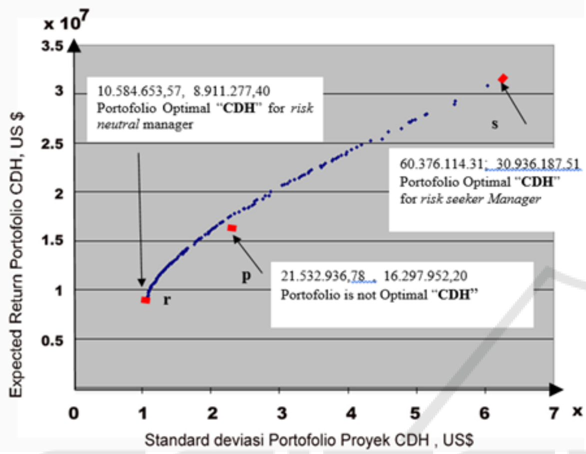


Figure 4: Various optimal portfolios of "CDH" based on investor preferences on the efficient frontier curve

4 CONCLUSIONS

The electricity industry has evolved from a vertically integrated state-owned monopoly company (not subjected to the normal rules of competition) to a liberalized market where generators and consumers have the opportunity to freely negotiate the purchase and sale of electricity.

With the shift in the paradigm of electricity supply, producers are faced with variations in the choice of generation systems and character loads / customers that are always dynamic.

Risks and Expected Economic returns are to be a measure for producers to choose a combination / portfolio of power plant systems to be operated.

By using the Markowitz efficient curve portfolio, the optimal portfolio combination can be determination. The optimal Portfolio model with the Markowitz model chosen from the many efficient portfolio alternatives that can provide a certain level of return in accordance with the risk dared to be borne by the manager.

Producers who dare to face risks will choose a portfolio combination that is on the rightmost efficient curve, and if you want to avoid risk the producer will choose a portfolio combination that is left most on the efficient curve

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