Generation Unit Commitment in Microgrid with Renewable Generators and CHP

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***Abstract*— Nowadays, renewable energy play an important role to power system generation, the installation of renewable generators is increasing in distribution systems in the form of microgrid. Microgrid is able to increase efficiency of power generation. The fluctuation of renewable generators in microgrid affects to power quality and reliability in the power system. These problems can be solved by the installation of battery in microgrid. The proposed algorithms consist of correlation between solar irradiation and temperature model. The output power and useful heat can be calculated by steady state model. Generation unit commitment will be covered with combined heat and power (CHP) to increase fuel efficiency. Therefore, an appropriate battery capacity is investigated in this paper. Lead-acid battery is the proposed battery that used in this paper. The proposed algorithm has been tested with IEEE14 buses. Satisfactory results were obtained.**

***Keywords*— Copula, Monte Carlo Simulation, power Fluctuation, Appropriate Battery Cappacity, Lead-Acid Battery**

I. INTRODUCTION

Presently, the energy resource used to produce electricity is divided into two categories, i.e. non-renewable energy and renewable energy resource.

The non-renewable energy, such as coal oil and natural gas, is the primary source which used to generate electric power in Thailand. According to the Power Development Plan (PDP) 2010, due to the increase of the power demand, the electricity generating capacity has to increase. The production of electricity from fossil fuels will impact the environment, such as greenhouse gas emissions, nitrogen compounds emissions that cause acid rain, etc.

One of the key objectives of the PDP 2010 is to increase the number of renewable energy power plants. The renewable energy resource, such as wind, sunlight, rain, tides, waves and geothermal heat, is energy extracted from natural resources which cause the positive environmental effect. Thus, the renewable energy has an important role to increase fuel diversity which also increases reliability of power system. Therefore, the power generation from the renewable energy is increasing because power generation from renewable energy is widely regarded as a clean energy and will not be the end. Furthermore, renewable energy does not pollute the environment and it is able to reduce the production of greenhouse gas emission as well.

Although, the renewable energy power plants will provide many advantages, there have many disadvantages. One of the most anxious impacts is the fluctuation of the renewable energy resources. Due to the intermittent behavior of renewable energy generators, the management of renewable generators is the important problem. In the power system connected with the renewable energy power generators, if they have poor management; it may decrease the power quality and power reliability in the power system.

The concepts of Microgrid as an alternative approach for integration small scale distributed energy resources into distribution system. It is a group of small sources and loads within a local area which can be characterized as the independent system that provides heat and power to its area although it disconnected from the centralized grid and can be connected to other grid [5].

The fluctuation of renewable energy resources can be represented by stochastic method. In order to make microgrid as the virtual power plant, a battery energy storage is required to reduce the intermittency of renewable energy power by storing energy when the surplus energy occur and re-dispatching at the peak load time or when the system is shortage of energy[5].

There are three steps of this methodology to determine the appropriate battery capacity. Firstly, finding interdependency between two parameters consist of solar radiation and ambient temperature from Statistical data for determining joint cumulative probabilistic distribution of them, this step shows that two parameters correlate each other. Secondly, use Ito's Lemma and Copula to forecast power that is generated by renewable energy generators. The last step, generation unit commitment is used to determining appropriate capacity of energy storage system in microgrid with renewable generators and CHP[8]-[9].

II. SYSTEM CONFIGURATION AND MODELLING

This paper use IEEE 14-BUS is a case study. A wind turbine connected at bus 2, a photovoltaic connected at bus 3, two CHP connected at bus 5 and 6, a gas engine connected at bus 8 and BESS installed at bus 1. In this microgrid, it consists of electrical and two heat loads. The electrical load already have in IEEE 14-BUS and two heat loads will be assigned to connected at the same bus that CHP installed. The heat system will be explained in Appendix.

A. Extracting Parameters

There are two renewable energy generators be considered in this paper, i.e., photovoltaic generators and wind generators. Because of the intermittency of renewable energy resource, the values of wind velocity, solar irradiation and ambient temperature will be forecasted.

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1) Wind Speed Model

The intermittent problem of wind velocity can be separated into two parts, shown by

$$v_{w,t} = v_{trend,t} + v_{noise,t} \quad (1)$$

Where $v_{w,t}$ is wind velocity at any time consideration. $v_{trend,t}$ is an average hourly wind velocity and $v_{noise,t}$ is an uncertainty of wind velocity. It can be characterized as normal distribution with zero mean and time dependent variance, $v_{noise,t} \sim N(0, \sigma^2 v_{w,t}^2 t)$. Ito's Lemma is used to apply to equation (1) and $v_{w,t}$ will be expressed as

$$v_{w,t} = v_{trend,t} \cdot exp\,(-\frac{1}{2}\sigma_{trend,t}^2 t + \sigma_{trend,t} Z\sqrt{t}) \quad (2)$$

where $\sigma_{trend,t}$ is an hourly standard deviation of wind velocity, Z is a standard normally distributed random number, and t is a point of time in consideration. The maximum likelihood method is used to calculate the optimal value of $\sigma_{trend,t}$.

2) Solar Irradiation And Ambient Temperature Model

In fact, solar irradiant and ambient temperature is related together. If that day has a high solar irradiation, an ambient temperature will be high. On the other hand, if that day has a low solar irradiance, it may cause the low ambient temperature. Therefore, the correlation between the solar irradiation and the ambient temperature are taken into account to determine the generated power of PV array.

Copula is the kind of distribution function, that used to describe the dependence between multi-random variables in form of joint cumulative distribution function. The main principle of copula is Sklar's Theorem [2],[6]-[7] that defines H is a joint cumulative distribution of two random variables if it has a copula C. It can be expressed as

$$H(x, y) = C(F(x), G(y)) \quad (3)$$

Where $x, y \in R$ and $F(x), G(y)$ are the marginal cumulative distribution of x and y respesctively. However, the model of $F(x), G(y)$ have to be the time varying characteristic as

$$G_t = G_{avg,i} + \sigma_{G,i} G_t Z_{G,i}\sqrt{dt}) \quad (4)$$

$$T_{ambient,t} = T_{avg,i} + \sigma_{T,i} T_{ambient,t} Z_{T,i}\sqrt{dt}) \quad (5)$$

Where G_t an irradiation at any is time consideration, $G_{avg,i}$ is an average irradiation at hour $i, \sigma_{G,i}$ is a variance of G at hour i, dt is a time period and $Z_{G,i}$ is a normal distribution of G at hour i. Detail of parameter in (5) will be similar to (4).

The correlation between G_t and $T_{ambient,t}$ can be determined by joint cumulative distribution between $Z_{G,i}$ and $Z_{T,i}$,$H(Z_{G,i}, Z_{T,i})$.

B. Generators Model

In this paper, there are five proposed generators in microgrid and one storage system, i.e. one wind turbine, one photovoltaic, one conventional generator as a gas engine, two combined heat and power (CHP) and one battery.

1) Wind generator model [3]

Wind turbine generates electric power from the kinetic energy of wind velocity and changes it to pneumatic power. This power depends on each state of wind velocity, can be express as

$$P_{WIND} = \begin{cases} 0 & , \quad V < V_{ci} \\ \dfrac{V^3 - V_{ci}^3}{V_r^3 - V_{ci}^3} \cdot P_r, & \quad V_{ci} < V < V_r \\ P_r & , \quad V_r < V < V_{co} \\ 0 & , \quad V < V_{co} \end{cases} \quad (6)$$

Where V is wind velocity at the time consideration (m/s), V_{ci} is cut-in speed (m/s), V_{co} is cut-off speed (m/s), V_r is rated speed (m/s), P_r is rated power of wind turbine (kW) and P_{WIND} is output power from wind turbine (kW).

2) Photovoltaic Generator model [1]

Photovoltaic generator can absorb the solar energy to generate the electric power by rely on solar cells. Amount of electric power depends on solar irradiance and temperature at state, can be express as

$$P_{pv} = \eta_{conv} \cdot P_{STC} \cdot \frac{G_{INC}}{G_{STC}} [1 + k(T_c - T_r)] \quad (7)$$

Where P_{pv} is the generated electric power (kW), P_{STC} is rated capacity of photovoltaic power at standard test conditions (STC), η_{conv} is expressed as the loss of the converter, G_{INC} is an incident irradiance, G_{STC} is solar irradiance at STC, k is temperature coefficient of power equal to -0.045, T_c is the cell temperature and T_r is the referent temperature.

3) Conventional Generators Model

Basically, conventional generators have the same model but they differently have the ramp rate of each other. Generators can't generate power over than the ramp rate limit in a time interval, it can be expressed by

$$P_i(t) = \min\{P_i^{max}, P_i(t-1) + \tau \cdot RU_i\} \quad (8)$$

$$P_i(t) = \max\{P_i^{min}, P_i(t-1) - \tau \cdot RD_i\} \quad (9)$$

Where $P_i(t)$ is the output power at time t (MW), P_i^{max} is the maximum output power of unit i (MW), P_i^{min} is the minimum output power of unit i (MW), RU_i is the ramp up rate of unit i, RD_i is the ramp down rate of unit i and τ is the time interval is considering.

4) Combined Heat and Power Generator model

One of the highest efficient generators is Combined Heat and Power Generators. They can provide electric power and heat to customers. It plays an important role in microgrid because almost in microgrid consist of electricity and heat loads. In this paper, CHP model is divided into two categories, i.e. electric power generation model and useful heat model. The electric power generation model is the same as the other conventional generator model. The fuels source are burned to provide heat to the water in the boiler for generate high pressure stream and release to drive a turbine to generate the electrical power. The remaining heat is used to transfer to heat load. The useful heats depend on the electrical power that generated by CHP, heat rate curve (quadratic function), can be expressed as

$$H_{useful} = \beta \cdot (H_{in} - H_{elec}) \tag{10}$$

Where H_{useful} is the remaining heat from electric power generation that can use to provide the heat loads, H_{in} is the heats that come from the combustion fuels, H_{elec} is the output electrical power in the form of heat. β is the proportion between useful heat and waste heat.

C. Electrical and Heat Load model

Loads in microgrid are divided into two categories, electrical load and heat load. Loads in power system have an uncertainty. Therefore, it is defined as random variable, normal distribution. In this paper, daily load curve is considered to electrical load because loads at each the considering time has the different valves. All of the time considerations cover on one year.

D. Lead-acid battery model[4]

Typically, there are many types of battery storages. In this paper, lead-acid battery is chosen to store the electric power because the proportion between efficiency and price is higher than other and widely recognized by many producers. This proposed battery has 260 Ah of nominal capacity and 12 volt of nominal voltage.

III. Generation Unit Commitment in Microgrid with CHP

This session will explain about the unit commitment in microgrid with combined heat and power generator (CHP). It divided into two part, power flow calculation and generation unit commitment with CHP in microgrid.

A. Power Flow Calculation

One important of unit commitment is Power flow calculation because it is used to check the violation constrain of power system. Newton-Raphson is wildly recognized because its efficiency and reliability. It has the fast converge to solution and iteration independent from power system. Considering n bus power system and power inject to bus i, the power injected equation can be expressed as

$$P_{i,cal} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) \tag{11}$$

$$Q_{i,cal} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) \tag{12}$$

Active power and reactive power that are calculated from above equation will equal to the summation of dispatch power at each bus. The solutions of power flow calculation can be solved by

$$\begin{bmatrix} \Delta P_i \\ \Delta Q_i \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta_i \\ \Delta|V_i| \end{bmatrix} \tag{13}$$

Matrix $J = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix}$ is called Jacobian Matrix. From above equation, $\begin{bmatrix} \Delta\delta_i \\ \Delta|V_i| \end{bmatrix}$ can be solved by $J^{-1} \times \begin{bmatrix} \Delta P_i \\ \Delta Q_i \end{bmatrix}$ and then update voltage angle and voltage magnitude of each bus by

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \tag{14}$$

$$|V_i^{(k+1)}| = |V_i^{(k)}| + \Delta|V_i^{(k)}| \tag{15}$$

The process will run continuously until $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ (Power mismatch) less than tolerance value (); norm of $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ less than .

B. Unit commitment

Normally, unit commitment is the generation planning to meet the electrical load in each time consideration. Including the any constrains of power system. Generation power of generator has an increasing and decreasing limit (ramp rate), to change the level of power generation. The ramp rate of generators in this paper is defined in Appendix. Fuel cost in this paper is the quadratic function, can be express as

$$F_i(P_i^G) = a_i \cdot (P_i^G)^2 + b_i \cdot P_i^G + c_i \tag{16}$$

Startup generators cost;

$$SU_T = \sum_{i=1}^{N_D} \sum_{c=2}^{\bar{C}_i} H(T_i^C) \cdot SU_i \tag{17}$$

Shut down generators cost;

$$SD_T = \sum_{i=1}^{N_D} \sum_{c=2}^{\bar{C}_i} [1 - H(T_i^C)] \cdot SD_i \tag{18}$$

Where $H(\cdot)$ are unit step functions.

1) Objective function;

$$\text{Min} \quad F(P) = \textstyle\sum_{i=1}^{N_G} F_i(P_i^G) \tag{19}$$

2) Constrains;

a) Generated power of a generator and a system storage cannot over than ramp rate limit in a period.

$$\mathrm{E_i(t) = min\,\{E_i^{max}, E_i(t-1) + \tau \cdot RU_i\}} \tag{20}$$

$$E_i(t) = max\,\{E_i^{min}, E_i(t-1) - \tau \cdot RD_i\} \tag{21}$$

Where $\tau = 15\ min$

b) Generated Active powers have to meet loads in power system.

$$\sum_{i=1}^{N_D} u_i(t)P_i(t) + \sum_{i=1}^{N_{UD}} u_i(t)P_i(t) + \sum_{i=1}^{N_B} P_{i,BATT}(t) = \sum_{i=1}^{N_L} P_i^L(t) + P_{LS}(t), t = 1,2,\dots,T \tag{22}$$

c) At least, Generated heats must equal to heat loads.

$$\sum_{i=1}^{N_C} u_i(t)H_{CHP,i}(t) \geq \sum_{i=1}^{N_D} \left(H_i^L(t) + H_{LS}(t)\right), t = 1,2,\dots,T \tag{23}$$

C. Economic dispatch

Generally, unit commitment has to run with economic dispatch together because economic dispatch is the sub problem of unit commitment. Economic dispatch is purposed to serve all of the electrical and heats loads at the lowest cost. There are many methods to solve this problem, in this paper; Newton-Raphson is used to solve economic dispatch with the other constraint.

1) Heat Dispatch

Heat loads have an uncertainty, are generated by normal random distribution. They are installed at CHP installation bus and connect together with the pipe which generates heat loss if the heat transportation has occurrence. Heat transportation from the sending end, receiving end and in pipe transmission, respectively, can be showed by

$$H_{tran,s} = H_{CHP,s} - H_{load,s} \tag{24}$$
$$H_{tran,r} = H_{load,r} - H_{CHP,r} \tag{25}$$
$$H_{tran,s} = H_{tran,r} + H_{loss} \tag{26}$$

In this paper; the heat loss consideration will focus on only two parts; convection and head (friction) losses. Total heat loss, H_{loss}, is the summation between head loss, consist of major loss and minor loss, and convection loss.

a) Convection losses

Convection losses will happen when the heats transfer between the different temperature places. This paper use it for calculate loss from inside the pipe, high temperature, to outside the pipe, low temperature. It can be explained by

$$H_{loss,conv} = \frac{T_1 - T_2}{\frac{1}{2\pi L h_1} + \frac{\ln(r_2/r_1)}{2\pi k L} + \frac{1}{2\pi L h_2}} \tag{27}$$

Where T_1 is inside pipe temperature, T_2 is ambient temperature, L is Length of heat transfer pipe, h_1 is convection coefficient of stream inside the pipe, h_2 is convection coefficient of the air, k is conduction coefficient of pipe, r_1, r_2 are radius inside and outside pipe, respective.

b) Head losses

Head losses are generated by friction between the wall of pipe and the fluid. The head loss for fluid flow is directly proportional to the length of the pipe, as flow rate increases – power increase - the pressure will drop. Friction factor can be divided into two part, major loss and minor loss. The losses from friction due to frictional effects in fully developed flow throw in constant-area tubes are called as "Major loss" and the resulting losses from entrancing, fitting, area changes are called “Minor Loss”. Because the pressure drop analysis cannot be evaluate. Thus, turbulence flow is used to calculate the major losses and can be expressed as

$$h_l = f \frac{L}{D} \frac{\bar{V}^2}{2} \tag{28}$$

Where h_l is the major losses, L is pipe length, D is pipe diameter, $\bar{V}$ is average flow velocity, f is the friction factor can be calculated by (29)

$$f = 0.25\left[\log\left(\frac{e/D}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^{-2} \tag{29}$$

Friction factor is the function of roughness wall, e, pipe diameter, D, and Reynolds number, Re, is the proportion directly to the power output that depends on fluid density, ρ, average flow velocity, $\bar{V}$, pipe diameter, D, and fluid velocity, μ. It can be showed as

$$Re = \frac{\rho \bar{V} D}{\mu} \tag{30}$$

Because heat loss isn’t constant value but it depends on heat transportation. So, heat loss calculation can be solved by Newton-Raphson method.

IV. Determining The Appropriate Battery Capacity

Power flowing into bus and out from bus can be calculated by

$$P_{batt} = P_{Load} - P_{Gen} \tag{31}$$

Where P_{Load} is a forecasting load in one time consideration. P_{Gen} is the summation of power between renewable and non-renewable generators, i.e., the generated power from a wind turbine, a photovoltaic, two combine heat and power generators and a gas engine generator.

Mismatch power between P_{load} and P_{gen} show about the lack energy when P_{batt} is positive values, battery has to dispatch power to the grid. The surplus energy occur when P_{batt} is negative values, battery has to store the excessing power from renewable generators.

To determine the appropriate battery capacity, can be calculated by

$$C_{opt} = \frac{P_{BATT}}{V \cdot I_{max}} \cdot C \tag{32}$$

Where C_{opt} is the appropriate battery capacity, V is the nominal voltage of battery, I_{max} is the maximum charging/discharging current; this paper equal to 50A, C is a battery capacity.

V. Experimental Results

A. Example of Wind Speed, Solar Irradiation and Ambient Temperature Sampling

1) Wind Speed Sampling

The sample of wind speeds in a day is represented as Figure 1. It is generated by using the average hourly wind speeds. Time interval for simulations is 15 minutes. The sampling of wind speed can be calculated by equation (2)

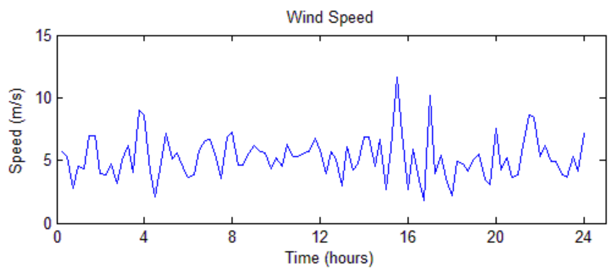

Figure 1. Example of the Wind speed in a Day

2) Solar Irradiation and Ambient Temperature Sampling

To Sampling the solar irradiance and ambient temperature, the average values and standard deviation of data be defined in Table I.

TABLE I. THE AVERAGE AND VARIATION OF IRRADIATON IN WINTER

hour	$G_{avg}\left({kW}/{m^2}\right)$	σ_G	T_{avg}(°C)	σ_T
7	0.0353	0.5036	17.2825	0.1977
8	0.1528	0.7286	18.4875	0.1759
9	0.3596	0.6891	20.7800	0.1420
10	0.5488	0.7012	23.0358	0.1161
11	0.6686	0.4990	25.4908	0.0877
12	0.7017	0.4695	27.115	0.0807
13	0.6725	0.6359	28.0475	0.0807
14	0.5818	0.6842	28.8625	0.0779
15	0.432	0.8202	29.1808	0.0794
16	0.2311	1.2380	29.2525	0.0867
17	0.0627	1.1117	28.3758	0.0930

The sample of solar irradiance and ambient temperatures are generated by (4)-(5). Figure 2 represents the sample of irradiance and ambient temperature in one day by using the sampling time interval as 15 minutes.

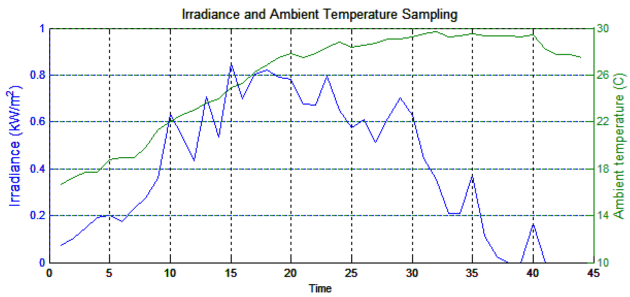

Figure 2. Example of Solar Irradiation and Ambient Temperature

B. Example of Generated Power

1) Example of Generated Wind Power Sampling

To calculate generated wind power. The wind speed data that has been sampled, the explained equations in the session II are the apparatus to calculating. The results of generated wind power can be shown in Figure 3.

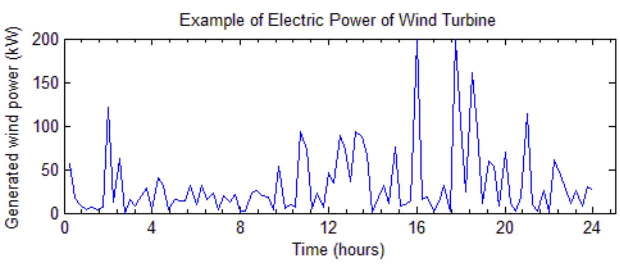

Figure 3. Example of a figure caption. (figure caption)

2) Example of Generated Photovoltaic Power Sampling

This paper use a 200 kW installed photovoltaic generator[1]. When both solar irradiance and ambient temperature have been sampled, the generated power from photovoltaic can be calculated by the equation explained in session II. The generated power, flow through the inverter, convert the electric power from DC to AC electricity. The results can be represented in Figure 4.

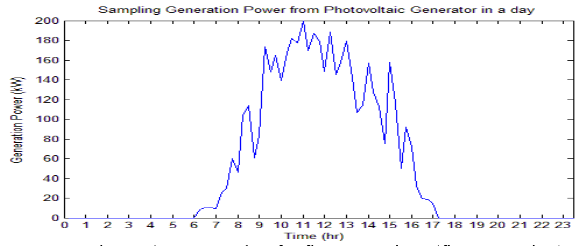

Figure 4. Example of a figure caption. (figure caption)

C. Example of Generation Unit Commitment in Microgrid

The sample of the generation unit commitment can be represented in TABLE II and explained below.

TABLE II. EXAMPLE OF GENERATION UNIT COMMITMENT

Event	PBatt	Pw	Ppv	Pchp1	Pchp2	Pgas
Event1	0	60.32	0	106.16	50.96	0
	0	15.622	0	121.16	75.96	5.30
Event2	0	10.67	113.78	63.12	30.30	0
	-27.56	169.47	60.65	50	20.00	0
Event3	0	101.24	0	95	58.13	0
	12.24	18.024	0	110	83.13	40

Event1: Generated power from renewable generators had reduced rapidly, at the same time; conventional generators (CHP1, CHP2) have to increase the generation power to meet the electric demand but they were limited by ramp up rated. Therefore, gas engine have to start up and shave the remaining load at this event.

Event2: Generated power from renewable generators had increased rapidly. Conventional generators have to reduce the generated power but still have the excessing power. Thus, battery has to store the surplus power at this event.

Event3: Generated power from renewable generators had increased rapidly over than summation of ramp down rated power of any generators. Therefore, battery has to dispatch power at the event.

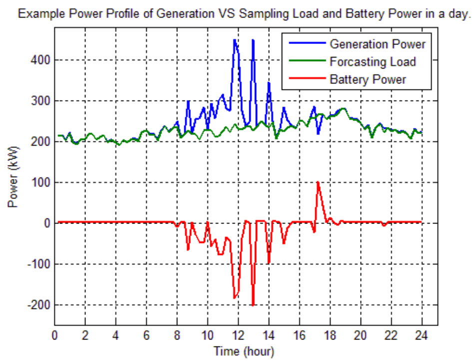

Figure 5. Example of a figure caption. (figure caption)

In a day, battery can be used anytime to store the surplus energy or re-dispatch power when the generators cannot follow the load rapidly. The examples of power profile of generation versus forecasting load and battery power are shown in the Figure 5.

D. Battery Capacity Determination

Determination of battery capacity in this paper can be computed by (31). The appropriate battery capacity can be calculated by applying the proposed battery model with the explained method in the section IV. The appropriate battery capacity in a year can be illustrated by a frequency distribution curve as

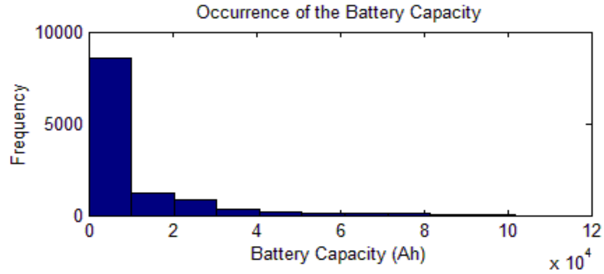

Figure 6. Example of a figure caption. (figure caption)

The offer size of appropriate capacity battery is at the 95th percentiles of battery capacity occurrences in a year. For the simulation, this paper have 1000 iterations to find the appropriate battery capacity that can be covered in 95% of confident interval. The frequency distribution result of 1000 scenarios is shown in Fihure 7.

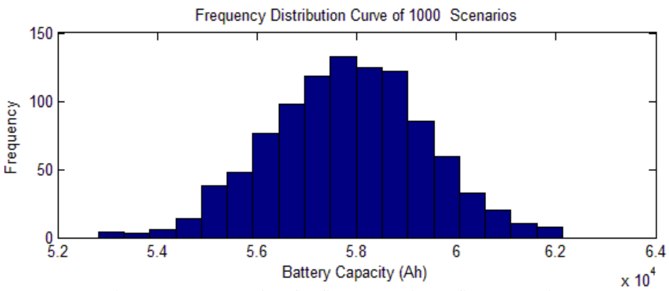

Figure 7. Example of a figure caption. (figure caption)

VI. CONCLUSION

Scenario one, determining battery capacity of renewable generator separately in micro grid, get the battery capacity of wind turbine size 2.4567e4 Ah and battery capacity of photovoltaic generator size 1.6491e4 Ah. Therefore, the summation of battery in microgrid equal to 4.1058e4 Ah.

Scenario two, determining battery capacity of micro grid consist of wind turbine and photovoltaic, get the battery capacity size 6.0944e4 Ah. This scenario has a bigger size of battery capacity.

The result show that the battery capacity will increase when wind turbine and photovoltaic is installed together because the fluctuation of renewable generated power. Sometimes, the renewable generated power may be increase or decrease together at the same time, the large battery capacity is the requirement to support these events.

VII. ACKNOWLEDGMENT

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IX. APPENDIX

Average electric and heat load in this paper can be shown from 1st to 24th hours in TABLE III-V, respectively;

TABLE III. DAILY AVERAGE ELECTRIC LOAD CURVE (W)

83.33	80.00	79.33	77.77	75.55	84	88.22	88.88	86.00	84.22	87.55	83.33
90.44	89.33	86.44	88.88	95.55	97.77	100	97.11	91.11	88.88	86.66	90.44

TABLE IV. DAILY AVERAGE HEAT LOAD CURVE (BUS 2,KW)

300	300	300	300	300	300	300	300	600	600	900	900
900	900	600	600	300	300	300	300	300	300	300	300

TABLE V. DAILY AVERAGE HEAT LOAD CURVE (BUS 3,KW)

200	200	200	200	200	300	300	300	600	600	600	600
600	600	600	600	600	600	300	200	200	200	200	200

Specification of wind turbine has 200 kW / V_{ci}=2.5 / V_r=10 / V_{co}=20 (m/s).