Design of Optimal Sizing for New and Renewable Hybrid Generation System for Building Traffic Information System in Energy-Isolated Areas

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Abstract. A hybrid system consists of two or more different types of new and renewable energy generation systems. The hybrid generation system is more effective than the utilization of a single renewable energy resource. This study presents a method to design the optimal combination and unit sizing for new and renewable hybrid systems. The method is to find the optimal configuration and sizing among sets of system components, that meets the desired system requirements. This is to verify usefulness of this study through experiments by applying to traffic information system and consisting of an optimal combination with utilizing the proposed method

Keywords: System of Traffic Information; Optimal Design of Hybrid Generation System; New and renewable energy;

1 Introduction

It is necessary to supply energy from outside to build intelligent traffic information system in the energy-isolated areas. Instead of by using non-renewable sources, the renewable energies are very important such as wind energy and solar energy have been in the spotlight as a solution of these problems.

However, these energies are somehow very difficult to produce continuously for long time duration without energy fluctuation. Accordingly, a combined generation system with using more than two systems simultaneously has been in the spotlight, rather than a single system.

Building a combined generation system can allow to produce and supply energy continuously with stable condition. In this study, we design each unit of hybrid generation system based on the given environment data, load capacity, power storage system, and verify feasibility of independent power capacity of the traffic information system through experiments. The study results revealed that the usefulness has been proved through the method of optimizing the power storage capacity, power shortage rate for capacity design and optimal generation capacity of renewable energy hybrid generation system.

2 Overview of the proposed system

In this paper, we intend to develop intelligent traffic indicator that can be installed on the roads in the energy-isolated areas. The traffic indicator is a system that can allow the LED traffic guide lamp to emit light according to the road conditions with judging the road environment, such as weather condition and day/night situation, by itself. The configuration of the system that is intended to develop in this study is shown in Fig 1. It has been consisted of combined generation type of power supply , meteorological information center, guide sign LED, and controller by using wind power and sunlight to secure the power independently in the energy-isolated areas.

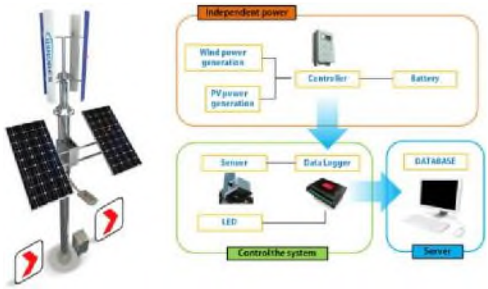


Fig 1. System Configuration

The power supply system that produces energy is designed, which is necessary to design based upon the capacity according to the load of traffic guide indicators. Table 1 shows the load capacity necessary for this system. The load capacity is designed with respect to time by the consumed power of each load, as below shown. The capacity for each unit of combined generation, based on the number of cloudy days (4 days) for expected total power consumption 454w.

Table 1. The required electric power

Load	The consumed time	The consumed electric power	Total electric power
LED streetlight	8 hour after sunset	8hour×40W	320W
LED road sign	Approximately 8 hour	8hour×5W×3set	120W
RT60	24hour	24hour×0.5W	12W
Total			454W

3 Mathematical Modeling of hybrid system components

3.1 Modeling of Generator System

There are many types of wind generators with different power output curves, so that the model used to describe the performance of wind generators are expected to be different. The mathematical model of wind turbine output can be defined as

$$P_W = \frac{1}{2} C_P \rho A V^3 \qquad (1)$$

Where, □ is air density, □ is diameter of rotor, v is wind speed, and C_P is the power coefficient.

If the solar radiation strikes on the tilted surface, the ambient temperature and the manufacturers data for the PV modules are available, the power output of the PV generator, P_{PV}, can be calculated according to the following equations:

$$P_{PV} = \eta_g N A_m G_t \qquad (2)$$

Where, η_g is the instantaneous PV generator efficiency, N is the number of modules, A_m is the area of a single module used in a system and G_t is the global irradiance incident on the titled plane.

3.2 Modeling of Battery System

Since the state of battery is related to the previous state of charge, the energy production and consumption situation of the system during the time from *t-1* to *t*, it should be modeled differently according to the generation and load conditions. When the total power from the hybrid generation system is greater than the load required, the battery is in charging state and modeled as follows;

$$C(t) = C(t-1)(1-\sigma) + \left(E_G(t) - \frac{E_L(t)}{\eta_{inv}}\right)\eta_{bat} \qquad (3)$$

On the other hand, when total power is less than the load demand, the battery is in discharging state and modeled as follow;

$$C(t) = C(t-1)(1-\sigma) - \left(\frac{E_L(t)}{\eta_{inv}} - E_G(t)\right) \qquad (4)$$

During discharging process, the battery discharging efficiency was equal to 1, and during charging, the efficiency is 0.65 to 0.85 with respect to charging current.

3.3 Design model of optimal sizing

If the power generated by the hybrid system is less than the load demand, the batteries should supply the energy deficit. However, if the battery capacity reaches to the minimum capacity stat, C_{min}, in which the batteries cannot discharge anymore the hybrid system can not supply energy deficit. In this case the power deficit must be supplied from the external energy system. The power deficit in this case is called as ' Lack of power', P_{LP}, and can be defined as:

$$P_{LP}(f) = P_{load}(t)\Delta t - (P_G(t)\Delta t + C(t-1) - C_{\min})\eta_{inv} \qquad (7)$$

Where, $P_G(t)$ and $P_{load}(t)$ are total power and load power requirement. $P_{load}(t)\Delta t$ represents total load demand power, and the last term represents the power consumed by the load. In Eq.(8), it is assumed that the power generated by the hybrid system during Δt is unchanged. 'The ratio of lack of power'(RLP), R_{LP}, for a period T, can be defined as the ratio of total lack of power over the total load required during that period.

$$R_{LP} = \frac{\sum_{t=1}^{T} P_{LP}(t)}{\sum_{t=1}^{T} P_{load}(t)} \qquad (8).$$

4 Results

4.1 Design condition

Design condition as shown in Table 2.

Table 2. Design Conditions

Type	Unit size	Total size	Cost(won/Wh)
Wind	200W	200W	105
PV	40W	To be designed	640
Battery	100Wh	//	320
load	-	25Wh	-

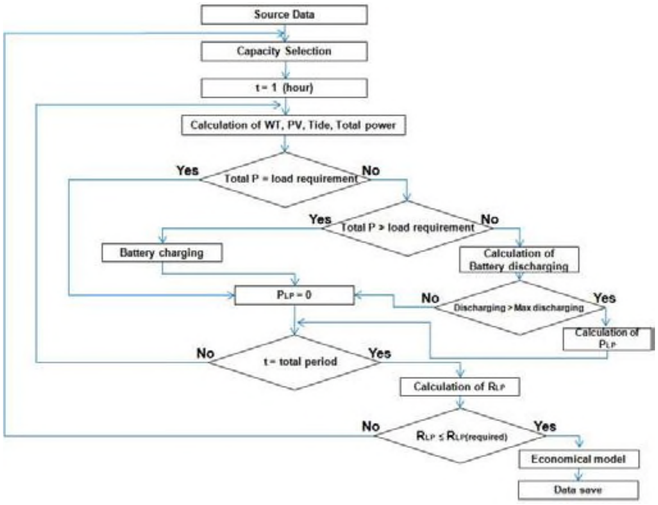


Fig 2. Flowchart of optimum design.

Fig.2 shows the algorithm of the design of optimal combination and sizing of the hybrid system. It assumes a combination of the size of each component of the hybrid system. Using the given data, it calculates the total power generated by the hybrid system. The power is then compared with the required power by the load.

4.2 Data measured

We have measured the wind velocity, solar radiation in a certain location to apply the optimal designing method of combined generation to wind power and sunlight power generation.
In this study, we have secured the data for 30 days to evaluate the performance of the designed system and verification of the optimal designing methodology, although the 1 year data should be needed to process a r eliable design. The amount of wind velocity resources and the quantity of solar radiation are shown in Fig3 and Fig4.

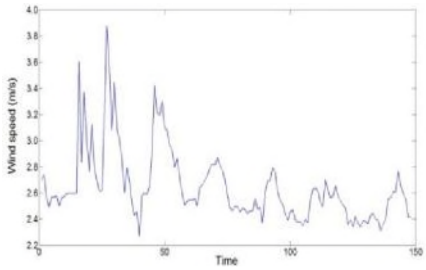


Fig 3. Wind data

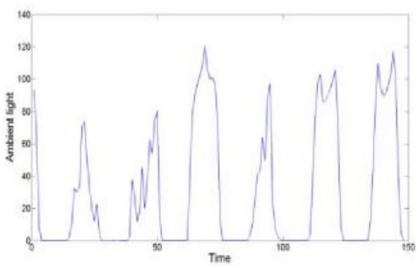


Fig 4. Irradiance data

4.3 Simulation Results

Fig.5 shows the results of PV generation system, with respect to battery sizes when the wind and load systems are fixed.

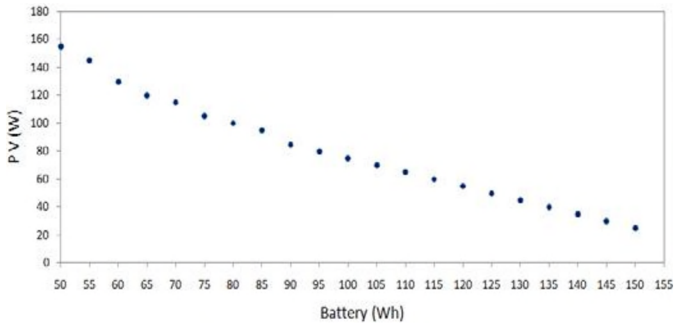


Fig 5. Design result (Wind 100W)

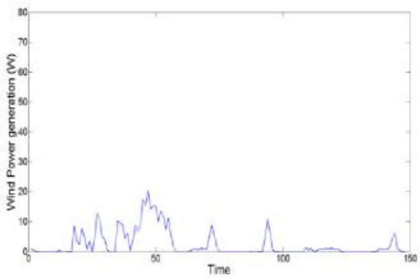
In this figure revealed that the combinations of sizes that satisfy the required R_{LP}. Among the combinations the optimal one that can satisfies the optimal model as given in table 3. These results can be different when the cost of each component has been changed.

Table 3. Results of Optimal Sizing

Type	Size	remark
Wind	200W	1 set
PV	80W	2Panel
Battery	100Wh	12V - 100Ah

4.4 Result

Finally the optimal generation combination has been selected, we have figure out each generations and change of battery charge by applying the resource datas in the same period. The power energy generated from the wind power generator and the solar generator are shown in Fig. 6 and Fig.7.



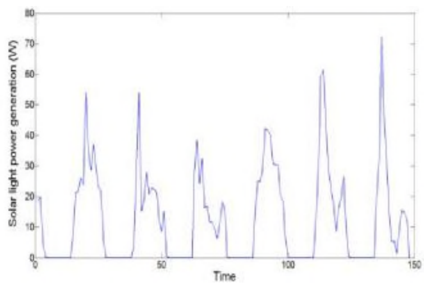


Fig 6. Wind Power **Fig 7.** PV Power

Fig. 8 shows the status of battery charge for each time zone.

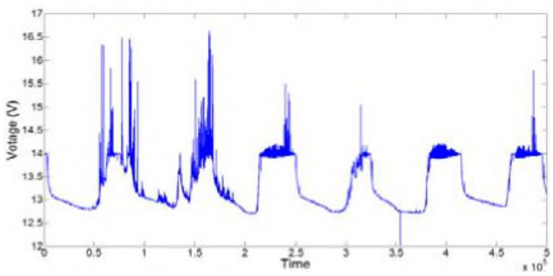


Fig 8. Battery Charge Status.

5 Conclusion

In this study, we have studied the method of designing optimal generation capacity and optimizing the accumulated capacity to supply energy needed in the energy-isolated areas. For this, we have proposed the capacity designed model based on power shortage rates and verified it's feasibility by using conducting actual capacity designing. First, we have suggested the basic principle of the wind power and sunlight power generation system. After that the output of the individual system and the modeling of accumulated system. Based on this, we have also proposed the method of finding the optimal capacity combination of each unit generation system according to the power shortage rates. Thus, we have conducted the experiments of designing traffic information system by applying the optimally designed result to wind power and solar combined generation system. As supplying the stable power to load, we could confirm that the unused power had been discharged due to abandoned power, as it was, and all the transformation loss as the most generated power was larger than the required load and the battery was fully charged.

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