A Study on the Increase of renewable energy supply ratio for the school building applied PV system

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ABSTRACT
Recently the renewable energy has been used widely and the importance of renewable sources is bigger than before. And the government enforced a law to the public buildings to install the renewable energy facilities. The capacity of facilities was 5% of total construction cost until April 13, 2011. Since then, the government changed the law from 5% of total construction cost to 10% of predicted energy usage for the reasonable use of the renewable energy facilities. In this study, the comparative analysis is conducted according to the law to the building installed PV system through the Energy Plus simulation. And the method for improving renewable energy supply ratio was analyzed using existing PV array. Adjusting the PV array angle is the best way to generate more electric power without additional fee. When applying the month optimum angle, 3,600kWh of electric power are more generated compared to the existing angle.

KEYWORD
Renewable energy, PV system, Public building, Energy Plus simulation

INTRODUCTION

Recently, the whole world pays attention to the renewable energy to replace fossil fuels and reduce green-house gases. Developed countries such as United States, Europe and Japan exploit and disseminate alternative energy at national level. Korea lacks energy and therefore, heavily relies on foreign countries and the dependence takes about97%. Because of the demand-supply instability of energy, Korea is accelerating the exploitation and dissemination of renewable energyto secure energy stably. As one of those policies, the government has been enforcing a law to the newly constructed public building which its total floor area is over 3,000-squre-meter since 2004. According to the law, we should invest more than 5% of total construction cost

to install the renewable energy facilities. It started from the public buildings and as a result,the ratio to introduce the renewable energy facilities reconstructed buildings. Since then, however, the government changed the law from increased. In March 2009, the use of the law was expanded to extend and 5% of total construction cost to 10% of predicted energy usage for the reasonable use of the renewable energy facilities. The government will intensify the related regulations.

Therefore, this study analyzes the renewable energy supply ratio about the public buildings constructed before revision of the law. These buildings have renewable facilities built with the use of 5% of total construction cost. In addition, we try to figure out the ways to improve efficiency using the existing renewable energy facilities without any extra costs.

This study analyzed PV system and renewable energy supply ratio of the business facilities with the solar energy generating facilities in K University located in Gumi, Korea. Besides, we looked into the ways to improve efficiency using the existing solar energy generating facilities.We used Energy Plus simulation as a method of energy analysis.

OVERVIEW OF PV SYSTEM

1) Building Summary

Aoffice building at K University located in Gumi, Gyeongbuk, Korea was selected as an object building. The building was completedin December, 2010 and 5% of its total construction cost was invested in PV system. PV system started generating from February, 2011.Table 1 is the outline of that building.

Table 1 Building outline

Lists	Contents
Location	Gumi, Gyeongbuk
Use	Office
Building Size	First basement level, 7 stories.
Building area	2,611m^2
Architectural area	6,580m^2

2) PV system Summary

196 of PV modules were installed as 14 series x 14 parallels. Total installation capacity of the system was 41.16kWp. Table 2 shows the specification of installed PV module.

Table 2 PV module

Lists	Contents

Model Name	SMT210-S6
Rated capacity(Pm)	210W
Rated current(IPm)	7.91A
Rated Voltage(VPm)	26.55V
Short circuit current(Isc)	8.69A
Open circuit Voltage(Voc)	34.15A
Size(W×D×H)	1,459×979×40 mm
Weight	17.2Kg
Angle	15°
Azimuth	Southwest 15°
Tolerance	±3%

3) Analysis of the Output of PV system

We analyzed the daily output on a specific date (May 18, 2011) to figure out the generating efficiency of currently installed PV system. The biggest output was 25kWh at 11 AM to 12 PM. The insolation output was 215kWh in total. It is considered that there is no output after 5 PM because of the mountain located in the west of the object building.

THE ANALYSIS OF THE RENEWABLE ENERGY SUPPLY RATIO

1) Simulation

Google Sketchup and OpenStudio were used to create the building geometry, and then input the details in energy plus.

The building was composed of 65 zones.After creating Geometry of the building, exterior walls, windows, inside walls, floors, roofs, ceilings, and material information was collectedthrough drawings. And 'Material' Class was applied to the properties of these.

The building is carried out heating and cooling by system air conditioner but, in this simulation ‘HVACTemplate:Zone:IdalLoadAirSystem’ was applied. It is assume that the air conditioning by ideal system according to the indoor loads.

Thetypical office building schedules such as the occupant, lighting and equipment schedules was used.

Weather data is the most important factor for simulation. But Weather data were used Deagu regional because of the lack of Gumi Weather data. The characteristic of the weather between two places were similar.

2) The reliability Analysis

Before analysis, PV System's generation reliability review was conducted.The reliability analysis method was used asMBE(Mean Bias Error). MBE can be quantitatively evaluated error of simulation results from the actual data. The formulas

are as follows:

$$\mathrm{MBE}(\%) = \frac{\sum_{\mathrm{Period}} (\mathrm{S}-\mathrm{M})_{\mathrm{interval}}}{\sum_{\mathrm{Period}} \mathrm{M}_{\mathrm{interval}}} \times 100 \qquad (1)$$

Where,
M : Actual data
S : Simulation results

In this case, the lower value of the calculated results,more accurate data. In general, these standards should be within ± 10%.

Table 3 shows a comparison of the actual electricity generation of PV systems and Simulation results.

PV systems from February 2011 to August 2011 were used. And the actual electricity generation was measured during the above period. In addition, simulations were performed in the same period.

MBE value was approximately 9.4%. Therefore, the results of simulations have reliability.

Table 3PV system production comparison

Month	Measured (kWh)	Simulation (kWh)	Month	Measured (kWh)	Simulation (kWh)
2	3,261	3,658	6	4,291	4,302
3	5,260	4,408	7	3,461	3,998
4	4,469	5,102	8	3,159	4,008
5	4,124	5,201	9	-	-

3)The analysis of the supply ratio of the PV system

Base on the reliability, the analysis of the supply ratio of the PV system were conducted through the simulation.

Table 4 shows the monthly building energy use through simulation, PV electricity generation and percentage of renewable energy supply ratio.

Table 4Simulation result of electricity consumption and PV production

Month	Electricity consumption (kWh)	PV Production (kWh)	Renewable energy supplyratio (%)
1	45,299	2,910	6.4
2	41,028	3,658	8.9
3	47,527	4,408	9.3
4	43,701	5,181	11.9
5	46,413	5,248	11.3
6	45,732	4,302	9.4

7	44,382	3,998	9.0
8	47,527	4,051	8.5
9	43,701	3,690	8.4
10	45,299	4,104	9.1
11	44,421	2,980	6.7
12	43,701	2,815	6.4

The results of the simulation, the energy supply ratio of PV system ranged from 6.4 to 11.9% monthly, and the annual average was 8.8 percent.

This means that the supply ratio of renewable energy did not satisfy the revised law of 10% of current energy consumption.

Buildings built before the revision of laws do not need to match. But the importance of energy and renewable energy laws will enhance the day. As a result, existing building needs to improve percentage of renewable energy supply ratio by renewable energy facility.

So, the method of increasing supply ratio of renewable energy was analyzed.

4)Alternative methods to improve the percentage of renewable energy supply ratio.

Through the following methods can improve therenewable energy supply ratio.

- Method using the existing renewable energy facilities
- Additional expansion of renewable energy facilities
- Improve the supply ratio through Building energy savings

In this study we looked for the ways to improve percentage of renewable energy supply ratio by using the existing renewable energy facilities.

- Solar array angle adjustment
- Install solar array tracking system
- Efficient as a module replacement
- Expansion of photovoltaic modules

Among the methods, the solar array angle adjustment has a huge impact on power generation performance. And the easiest way to improve the renewable supply ratio without additional costs.

In this study, the electricity generation was analyzed according to the various solar arrays angles. Table 5 shows the simulation CASE.

Table 5Simulation CASE

CASE 1	Existing PV array angle	
CASE 2	Optimum array angle for each region	No more cost
CASE 3	Seasonal Optimum array angle	
CASE 4	Optimum array angle for each month	
CASE 5	Fixed array to Tracking array replace	Additional cost

CASE 6	Module change	
CASE 7	Increase PV array area	

CASE 1 was applied 15 ° angles to the existing PV array of the object building.
CASE 2 and CASE 3 were applied optimum array angle for each region and seasonal optimum array anglerespectively. According to the literature,Gyeongbuk area has annual average 32 °, in the spring season (March-May) 19 °, summer (June-August) 2 °, autumn (September-November) 44 ° and winter (December-February) 57 °.
CASE 4 was applied to monthly optimal angle, the angle that represents the maximum electricity generation was chosen through the simulation.
CASE 5 was applied to tracking systems, this method used drive unit and optical sensor for vertical incident on PV array.
CASE 6 was applied to various PV modules,the moduleswere selected at the same manufacture company and have different performance. Table 6 shows the Characteristic of module.
CASE 7 was applied to more array number, this CASE is installed more PV array on the roof of building as much as possible. It can be 4.24 time expansion.

Table 6Characteristic of module

MODEL	Existing PV array	Changing PV array
MaximumPower [W]	210	230
Voltage atPmax [V]	26.55	29.08
Current atPmax [A]	7.91	7.91
Open circuitVoltage [V]	34.15	37.40
No. Of cells&connections	54 in series	60 in series

5) Analysis of the simulation results
Renewable energy supply ratio according to PV electricity generation shown in table 7.

Table 7Comparison of Renewable energy supply ratio

	Electricity consumption (kWh/yr)	PV production (kWh/yr)	Increasing amount to CASE 1 (kWh/yr)	Supply ratio (%)
CASE 1	538,730	47,345	-	8.8
CASE 2		49,406	2,061	9.2
CASE 3		49,889	2,544	9.3
CASE 4		50,904	3,559	9.4
CASE 5		62,135	14,790	11.5
CASE 6		58,880	11,535	10.9

CASE 7		211,094	163,749	39.1

CASE 1 is the same conditions as the building, and the annual electricity generation of 47,345 kWh.

CASE 2 was applied 32 ° what is a local optimal value and the electricity generation are more than 2,061 kWh compared to the CASE 1. The total generation of CASE 2 wasabout 49,406kWh, the generation was increased 4.4% to the CASE 1.

CASE 3, CASE 4 and CASE 5 was also compared to CASE 1. Each generation wasincreased about 2,544 kWh, 3,559 kWh,14790 kWh compared to CASE 1. The electricity generation was 49,889 kWh, 50,904 kWh, 62,135 kWh per year of electricity generation, respectively.

Based on the above results, the more electric generationcan be achieved through the adjusting the angle of the PV approximately 14,790 kWh per year in CASE 5.

CASE 6 is the same conditions as the building, but module change. The total generation of CASE6 was about 58,880kWh, the generation was increased 10.9% compared to the CASE 1.

CASE 7 was compared to CASE 1. CASE 7 was applied PV module expansion to 4.24 time, electricity generation was 211,094 kWh, increased 39.1% to the CASE 1.

Through thetable 7, renewable energy supply ratio can be increased with the adjusting the solar array angle. But there is limitation that increasing electric generation using the existing facilities. Therefore additional install should be considered.

CONCLUSION AND IMPLICATIONS

In this study, according to expansion of the use of renewable energy and enhanced legal regulations, the building PV system installed was analyzedabout renewable energy supply ratio and the method to improve electric generation .

The results of this study are as follows:

1) Existing buildinginvested 5% of construction costs was analyzed applying the revised law that renewable energy supply ratio should be above 10% of total energy usage in building. The object building show 8.8% of renewable supply ratio, and did not meet the revised law.
2) The method of increasing the renewable energy supply ratio without additional costs using existing PV system was analyzed. The method adjusting PV array angle is the easiest way to improve the generation without additional costs. The CASE 4 was more generate than CASE 1 about 3600kWh, 7.5% of generation increased.
3) The renewable energy supply ratio of CASE 4 was increased about 9.4% because of the increasing generation.
4) CASE 5 was increased about 14,790kWh by using the tracking unit.
5) CASE 6 was increased about 11,535kWh by replacing the high-efficiency module.
6) CASE 7 was applied to 4.24 time PV array number and was generated 211,094kWh, 4.45 times more than CASE 1.

These methods have limitations and the building energy-saving efforts will be needed to improve the renewable energy supply ratio.
Also Additional install to cost and function should be considered.

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