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An empirical study of performance characteristics of BIPV (Building Integrated Photovoltaic) system for the realization of zero energy building☆

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ABSTRACT

In this study, we analyze the performance characteristics of BIPV (Building Integrated Photovoltaic) system of Climate Change Research Building of National Environment Research Institution which was designed with the aim of zero carbon building. This building totaling 2449 m^2 is consist of five laboratories, PR (Performance Ratio) department, conference room and others, and the area of conditioned space is 1668 m^2. In addition, the remaining residual load was predicted to 99,200 kWh when load reducing system was applied such as insulation, exterior shading device and lighting control.

BIPV system, which is consist of three modules; G to G (Glass to Glass), G to T (Glass to Tedlar/Crystal) and Amorphous, has 116.2 kWp of total capacity, and is applied to wall, window, atrium and pagora on roof.

After the completion of building, the total amount of energy consumption and the gross generation of BIPV system were 104602.4 kWh and 105266.6 kWh through a year from April 2011 to March 2012, respectively. It was evaluated to achieve zero carbon building because the energy surplus was 664.2 kWh.

1. Introduction

Interest in zero-energy buildings is gradually increasing due to global warming and depletion of fossil fuels. According to the report of Pike research, the global market of zero-energy buildings will rapidly increase over the next 20 years, and it is expected to be worth about 690 billion dollars in 2020, and about 1.3 trillion dollars in 2035 [1]. During this period, an average annual growth rate is forecast to be 43%, and mainly EU countries are expected to contribute to the growth of the zero-energy building market significantly. Due to such high international demand and necessity, the technology for zero-energy buildings has been developed continuously.

The most important things are to introduce energy-saving techniques which consider the characteristics of buildings and to supply renewable energy effectively in order to implement the zero-energy buildings. Specifically, energy-saving techniques have been developed as the core technology to reduce heating and cooling energy of buildings, and zero-energy buildings with this technology need relatively more electrical energy as the usage of thermal energy is reduced [2–4]. Since electricity has emerged as an important energy source to implement zero-energy buildings, the technology of renewable energy sources including solar, wind, fuel cells, etc. has constantly advanced to produce and consume electricity in buildings on its own. The production system of renewable energy in small and medium-sized buildings is, however, limited to the photovoltaic system in the currently developed

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Nomenclature

A	area of array [m^2]
E_{AC}	AC energy output to the grid per year [kWh/year]
E_{DC}	array DC energy output per year [kWh/year]
F_{EL}	facility total energy load met by PV production [kWh/month]
GI	reference irradiation (1000 W/m^2)
H_{Id}	total in-plane irradiation per year [kWh/m^2/year]
L_C	capture loss [d/h]
L_S	system loss [d/h]
N_E	reference array efficiency [%]
N_{Total}	overall system efficiency [%]
PR	performance ratio [%]
T_{FE}	total facility energy use [kWh/month]
Y_A	array yield [d/h]
Y_F	final yield [d/h]
Y_R	reference yield [d/h]

technology level, so the research and dissemination for BIPV (Building Integrated Photovoltaic) system combining a building with the power generation system has been continuously expanding.

In this study, the power generation characteristics of the BIPV system and the energy self-sufficiency rate with the building load are analyzed through the experimental research on the BIPV system of the Climate Change Research Center designed to be a zero-energy building. The purpose of this research is to provide the reference data for the installation of a BIPV system to be the zero-energy building in the future.

2. Construction status of Climate Change Research Center

Fig. 1 and Table 1 respectively show a panoramic view and architectural overview of the Climate Change Research Center located in Gyeongseo-dong, Incheon-si and designed as two floors above ground and one underground building. Total floor area of the building is 2.449 m^2 and there are laboratories, conference room, small meeting room, resource center, staff lounge, international conference room, lobby, and showroom for the promotion of carbon-zero buildings and external events.

If each room is classified by type of heating and cooling system, the area for both heating and cooling, heating-only area, and non-heating and cooling area are 1677.9 m^2, 45.2 m^2, and 726.1 m^2, respectively.

The floor plan of the Climate Change Research Center is shown in Fig. 2, and the positioned shape is a south-facing rectangle to minimize the heat loss and to secure enough space for installation of facility of renewable energy using solar energy. Especially, the horizontal and inclined photovoltaic systems with a pergola shape are applicable on the roof.

In addition, the hot water heating system as well as the heating and cooling system is composed of a photovoltaic and a geothermal heat pump system, therefore only electricity as every energy source in the building is used.

3. BIPV system

Table 2 shows the specifications of the module installed in the building, and they consist of GtoG (Grass To Grass), GtoT (Glass to Tedlar/Crystal), and transparent types with 4 polycrystalline modules and 1 amorphous module. The maximum capacity among installed modules is 213 Wp with the highest efficiency of 11.65%,

Fig. 1. Panoramic view of Climate Change Research Center.

and other polycrystalline modules represent 8–10% efficiency. Some transparent thin-film modules with low efficiency are applied to consider the light of the building.

As described above, a total of 871 modules of 5 different types are installed in the building, and 15 arrays on the 1177.9 m^2 of installation area are connected by module type and installation location. The detailed specifications of installed solar cell array are shown in Table 3, and installation location is indicated in Fig. 3. Letters and numbers in Fig. 3 show the number of array connected to each inverter.

Table 1
Architectural overview of Climate Change Research Center.

Floor	Facility Category	Purpose	Area (m^2)
Basement	Common	Mechanical room, electrical room, generator room, control room	521.6
First floor	Promotion	Showroom	280.7
First floor	Promotion	International conference room	431.4
First floor	Promotion	Information, situation room	18.0
First floor	Promotion	Storehouse	11.3
First floor	Common	Restroom	22.6
First floor	Common	Hall	138.3
First floor	Common	EV	28.3
First floor	Common	Windproof room	28.3
Second floor	Research	Laboratory	412.1
Second floor	Research	Resource center	42.7
Second floor	Research	Conference room	92.0
Second floor	Research	Small meeting room	22.8
Second floor	Research	Resource archive	56.1
Second floor	Research	Staff lounge (M, F)	30.4
Second floor	Common	Restroom	22.6
Second floor	Common	Hall	153.6
Second floor	Common	EV	164.9
Second floor	Common	Hallway	164.9
Second floor	Common	Staircase	164.9
Gross floor area			2449.2