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Building Integrated Thin Film Photovoltaic Performance Modelling on Conventional Building

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Abstract. PV(Photovoltaic) technologies have been developed into many forms. The emergence of BIPV (Building Integrated Photovoltaics) technology, it is possible for a building component to have another function as an energy generator. The technology of thin film PV, can be used as glass in buildings. PV (Photovoltaics) thin films can be applied as windows glasses. For older or conventional buildings, it is necessary to modify the window to applying the BIPV system. To estimate the energy generated from the BIPV system, a study needs to be conducted. In this study case analysis, a BIPV will be applicate on conventional 4-storey office building. Simulation is done with SAM (System Advisor Model) software. For solar energy potential is obtained from PV GIS data. From the simulation, the 40% of transparency thin film PV that applied in conventional building has 6.8% of capacity factor and 9,761 kWh of energy generated in the first year. A single 0.72 m^2 CdTe thin film PV module can generate approximately 23.76-38.01 kWh/year. The thin film BIPV generation is very depending on PV shading, so it important to consider PV orientation and position.

INTRODUCTION

The Indonesian government to encourage the use of renewable energy, to achieve the target of the renewable energy mix of 23% by 2025[1]. Today, one of the most developing renewable technologies is PV technology. Electricity produced by PV is clean and silent. PV technologies do not use fuel other than sunshine, PV systems also do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health[2].

In BIPV system, the PV modules are integrated within the building structures. mainly into roof or façade. This includes the PV modules in the form of transparent or semi-transparent glass. The BIPV is installed considering the local weather conditions and the building architecture. In this case, the BIPV system will have some impact on the building structures and their functionality[3].

The conventional building is not designed for the optimum PV utilization. The optimum building for designed BIPV system should be consider the PV irradiance factor. The important factors such as shadowing effect, ambient temperature, the direction and the slope of the PV are to be considered to get higher power output and high efficiency in practical applications[4].

SAM software (system Advisor Model) is used to evaluate the plant's energetic and economic performances such as monthly energy production, annual energy output and levelized cost of energy[5]. From the description above, an analysis of BIPV application in conventional building would be done in this study to determine its performance.

In future trends, the use of renewable energy will be encouraged to reduce CO_2 emissions in accordance with Indonesian government regulations. A simulation is needed to estimate BIPV application performance. This paper

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will estimate the CdTe windows BIPV thin film application performance and contribution applied on 4 storey office building.

METHODOLOGY

This paper will model the thin film PV as windows glasses on conventional building. The building model is Environmental Study Center of Universitas Gadjah Mada. The building windows glasses would be replaced by 40% of transparency thin film PV. The modelling simulation would be done using System Advisor Model software. The result from this simulation is the thin film PV performance. The thin film of PV modules will be analyzed. The building is located at Yogyakarta province Indonesia. The weather data is gotten from PVGIS (Photovoltaic Geographical Information System)[6]. The modules data is gotten from the datasheet.

System Advisor Model Software

System Advisor Model is a modelling software that simulate techno-economic model for renewable energy power system. The power generated by system is the electricity generated by the renewable energy system after all losses and adjustments. The power generated from PV system calculated by SAM using following equation:

$$P_{gen} = N_{inv} P_{ac} \left(1 - \frac{L_{ac}}{100}\right)\left(1 - \frac{L_{ajust}}{100}\right) \tag{1}$$

N_{inv} = Number of inverters
P_{ac} = AC output of a single inverter (W)
L_{ac} = Total AC power loss (%)
L_{adjust} = Curtailment and availability losses (%)

Curtailment and availability losses (L_{adjust}) may be used to account for operating losses imposed on the system by factors other than the solar resource and system's design, such as forced, scheduled, and unplanned outages, or other factors that reduce the system's AC power output. The power of ac output of single inverter $P_{ac,}$ is depending on the solar irradiance incident on the array less any due to external shading, self-shading, and soiling. SAM has a 3D shade calculator features. The 3D shade calculator calculates a set of beam and diffuse shading losses from a three-dimensional representation of a "scene" that consists of the photovoltaic array and any nearby objects that might cause shadows to fall on the array. Active surface objects represent the photovoltaic array and a set of pre-defined three-dimensional shapes represent nearby shading objects[7].

Building Model

The applied thin film PV conventional building model is located in Yogyakarta, Indonesia (Latitude: -7.775, Longitude: 110.377). It is 4 storey office building, with conventional windows on each sides. It has total 246.24 m^2 of potential PV module that can be applied. The building is geometrically identical with building in the south. The building tilted 14.29^o to the east from the north as shown on Fig. 1.

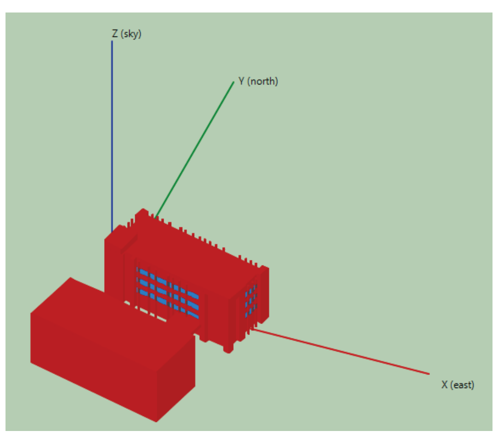

FIGURE 1. 3D model of the building

Thin film PV Module

The selection of thin film types used in the simulation is based on PV availability in the PV market. The thin film type used in this simulation is ST1-48W as can be seen on Fig. 2. It has 40% transparency thin film PV could replace glasses on conventional building. The thin film PV array divided based on building sides. The specification of this thin film module can be seen on Table 1[8].

FIGURE 2. 48W CdTe Thin Film BIPV

TABLE 1. ST1-48W specification

Specification	Value
Name	ST1-48W
Transparency	40%
Size	1200*600*6.8mm
Pmax	48 W
Voc	116 V
Isc	0.59 A
Vmpp	87 V
Impp	0.55 A
Cell type	Cadmium Telluride (CdTe)
Area	0.72 m^2

The model building is 4 storey building. Thin film PV applied on 2nd, 3rd, 4th floor. The first floor is not modelled because its windows is quite indented to inner building so the solar irradiance couldn't optimally irradiate the thin film PV windows.

Inverter

The GCI 2K 2G H US 240V[9] inverter is used in this simulation. The inverter is available on SAM inverter database. It has 400Vdc of DC input of PV module array. The detailed specification of the inverter can be seen on Table 2.

TABLE 2. The GCI 2K 2G H US 240V specification

Specification	Value
Name	GCI 2K 2G H US 240V
Total unit	4
Paco	1990 Wac
Pdco	2060.981445 Wdc
Pso	15.812385 Wdc
Pnt	0.597 Wac
Vac	240 Vac
Vdcmax	400 Vdc
Vdco	280 Vdc
Mppt_high	400 Vdc
Mppt_low	100 Vdc
Idcmax	7.360648 Adc

To define PV array that connected to inverter, it important to consider the number of modules per string. From the inverter specification it can be calculate the maximum number of thin film PV module series:

$$\text{Number of a seried module} = \frac{\text{inverter max Vdc input}}{\text{max Vdc module output}} = \frac{400\text{Vdc}}{116\text{ Vdc}} = 3.44 \sim 3 \text{ unit modules} \quad (2)$$

Thin film PV module array configuration can be seen on Table 3.

TABLE 3. Thin film PV modules array

	Subarray 1 (North side)	Subarray 2 (South side)	Subarray 3 (West side)	Subarray 4 (East side)
Modules per string in subarray	3	3	3	3
Strings in parallel in subarray	60	36	9	9
Total module	180 pcs	108 pcs	27 pcs	27 pcs
Thin PV module area	129.6 m^2	77.76 m^2	19.44 m^2	19.44 m^2
Orientation(azimuth)	14.29^o	194.29^o	284.29^o	104.29^o

SIMULATION AND RESULT

SAM simulation is done by inputting building location data, solar resources from PV GIS, PV module and inverter data. Then a 3D model is created to model shading in buildings. The type of the GCI-2K-2G-H-US 240V inverter used is already in the SAM database. The PV module parameters are adjusted to the PV module datasheet. Simulation is done assuming the window is closed so that the PV tilt is 90^o. Simulation result summary can be seen on Fig. 3:

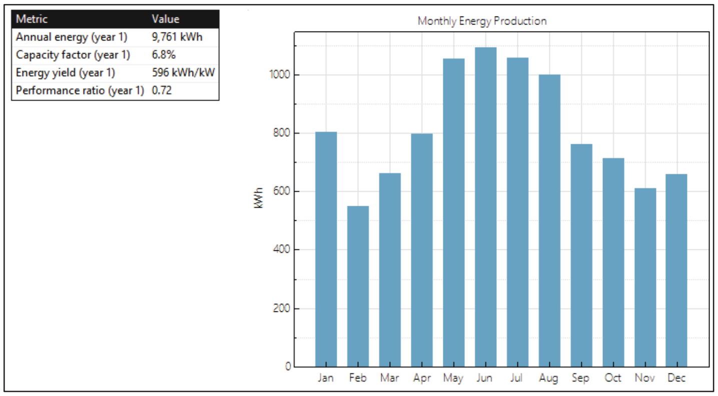

FIGURE 3. SAM simulation Result

The first year energy generated from thin film PV is 9,761 kWh with 6.8% of capacity factor. The peak month generation is occurred on June. The biggest PV energy generated from north side PV, followed, by south side PV, west side PV, and east side PV. To define the most effective PV module, it is needed to calculate energy generation per single module. From the calculation, the most effective PV module generation is west side PV module, followed by north side PV module, east side PV module, and south side PV module. The detail of PV module generation can be seen on Table 4.

Table 4. Subarray PV generation

Subarray	Gross DC energy Production in first year	Number of modules	Energy generated per modules in first year
Subarray 1 (north side PV)	6297.28 kWh	180	34.98333 kWh
Subarray 2 (south side PV)	2566.85 kWh	108	23.76713 kWh
Subarray 3 (west side PV)	1026.29 kWh	27	38.01074 kWh
Subarray 4 (east side PV)	880.621 kWh	27	32.61559 kWh

The daily profile of PV generation can be seen on Fig 4. From the graph, it can be defined that subarray 1 (north side PV) and subarray 2 peak energy generation occurred on 10-12 AM. The subarray 1 get bigger irradiance from the sun because it is not shaded, and because of the building is located on south hemisphere so it is more illuminated than subarray 2. The subarray 2 get less energy generated because it shaded by the building in the south. From the daily energy generation curve, the subarray 3 (west side PV) energy peak generation occurred on 1-4 PM. It happened because the subarray 3 faces to the west, and the sun position on the west start at 1-4 PM. Vice versa, the subarray 4 start the energy generation on 7-11 AM.

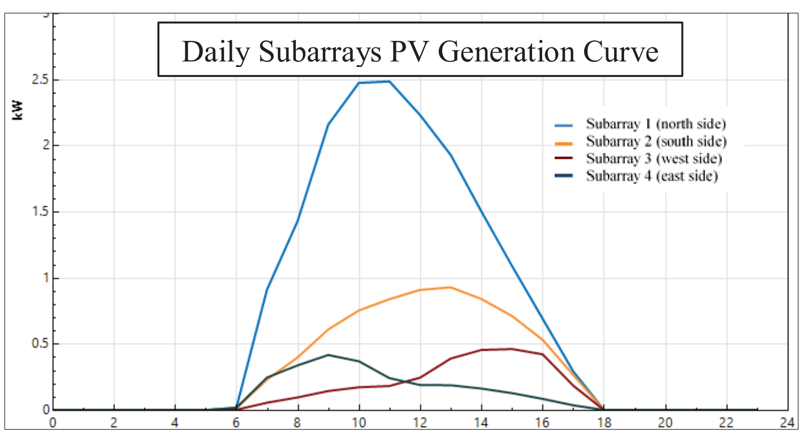

FIGURE 4. Average daily PV generation curve based on the subarrays

BIPV energy production can contribute 4.98% of total building load as can be seen on figure. 5.

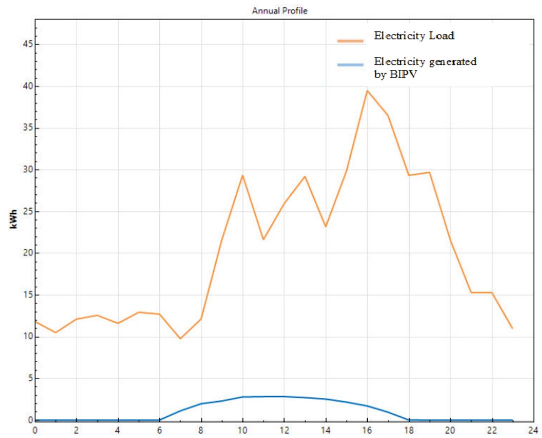

FIGURE 5. Average daily BIPV production vs electricity load

CONCLUSION

From the simulation, the 40% transparency thin film PV that applied as windows glasses in conventional building has 6.8% of capacity factor and 9,761 kWh of energy generated in the first year. A single 0.72 m^2 CdTe thin film PV module can generate approximately 23.76-38.01 kWh/year. The thin film BIPV can contribute 4.98% of total building load (485.32 kWh/day, 94.19W peak load). Amount of energy generated from thin film BIPV generation is very depending on PV shading, so it important to consider PV orientation and position. Because the capacity of the factor is still low, an economic study is needed if the thin film PV is to be truly implemented in order to achieve positive economic goals.

REFERENCES

[1] ESDM, *RUPTL PT PLN 2018-2027*. 2017.
[2] "Advantages and disadvantages of PV." [Online]. Available: http://www.energybc.ca/cache/solarpv/www.cetonline.org/Renewables/PV_pro_con.html. [Accessed: 17-Jun-2019].
[3] N. M. Kumar, K. Sudhakar, and M. Samykano, "Performance comparison of BAPV and BIPV systems with c-Si, CIS and CdTe photovoltaic technologies under tropical weather conditions," *Case Stud. Therm. Eng.*, vol. 13, p. 100374, Mar. 2019.
[4] A. K. Shukla, K. Sudhakar, P. Baredar, and R. Mamat, "BIPV based sustainable building in South Asian countries," *Sol. Energy*, vol. 170, pp. 1162–1170, Aug. 2018.
[5] M. Abbas, Z. Belgroun, H. Aburidah, and N. K. Merzouk, "Assessment of a Solar Parabolic Trough Power Plant for Electricity Generation under Mediterranean and Arid Climate Conditions in Algeria," *Energy Procedia*, vol. 42, pp. 93–102, 2013.
[6] European Commission, "Typical Meteorologial Year." [Online]. Available: http://re.jrc.ec.europa.eu/pvgis5/tmy.html. [Accessed: 17-Jun-2019].
[7] P. Gilman, N. A. DiOrio, J. M. Freeman, S. Janzou, A. Dobos, and D. Ryberg, "SAM Photovoltaic Model Technical Reference 2016 Update," NREL/TP--6A20-67399, 1429291, Mar. 2018.
[8] "40% Transparent Thin Film Solar Panel for BIPV," *GuaGua Technology*. [Online]. Available: http://www.gg-tech.net/en/solar-cells-panels/41-40-transparent-thin-film-solar-panel-for-bipv.html. [Accessed: 17-Jun-2019].
[9] "SolarHub - PV Module Details: GCI-2K-2G-H-US (240V) - by Ningbo Ginlong Technologies." [Online]. Available: http://solarhub.com/solarhub_products/57234-GCI-2K-2G-H-US-240V-Ningbo-Ginlong-Technologies. [Accessed: 17-Jun-2019].