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EFFECT OF AIR GAP ON PERFORMANCE ENHANCEMENT OF BUILDING ASSISTED WITH PHOTO VOLTAIC SYSTEMS

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ABSTRACT

This paper investigates performance improvement of room assisted with Photo voltaic (PV) system by varying air gap and PV glazing type. PV panel was installed on the south side of the room as Photo Voltaic Trombe wall (PV-TW) and over the roof. Performance was evaluated in term of cooling load, energy consumption and PV efficiency. Three different types of PV glazing (i.e. Single Glazing, Double glazing, double glazing filled with Argon gas) was tested by changing air gap between wall and PV panel for Malaysian climate. TRNSYS building simulation software was used in which various input parameters were inserted to obtain the results. It was found that maximum PV efficiency was achieved in the case of Double glass filled with Argon PV-TW at air gap of 0.2 m and roof pitch angle 20 degree. Ventilated PV-TW and PV panel installed over the roof also reduces cooling load of the room. Among all the three types of glazing, room assisted with Double glass filled with argon PV panel shows highest reduction in cooling load at air gap 0.2m and roof pitch angle 20 degree. Also cooling load of room reduced significantly with the increase in roof pitch angle upto certain critical angle which is different for different PV glazing.

Keywords: cooling load, photovoltaic trombe wall, TRNSYS, glazing type.

INTRODUCTION

Last few decades, there is a cumulative demand for development of sustainable buildings. Increase hazard of global warming and annihilation of fossil fuels has generated a necessity environment to develop eco-friendly natural energy systems in the buildings. The use of building integrated photo voltaic systems (BIPV) is gradually encouraged by national regulatory bodies, these system utilizes solar energy for heating and cooling of buildings [1,2,3]. PV-TW is the typical BIPV system which consists of south facing massive wall and PV panel, installed a few inches in front of the wall. The performance of PV devices is approximately inversely proportion to the cell temperature. Therefore, it is important to provide an adequate air gap behind the PV modules installed, either on the wall or over the roof of the buildings. This air gap will act like a ventilation in BIPV system. These types of ventilation not only reduce the temperature of PV panel, but also carry away the heat accumulated behind PV panel.

In the existing literature, there is no significant study has been done on air gap and its effect on the performance of BIPV systems. In practical the length of the air gap is not calculated with empirical relation rather it has been taken from earlier experiences. Researchers suggested that the minimum air gaps is roughly varies from several centimeters [4], with a minimum of 15cms gap [5]. There is no clear study has been done on the optimum air gap size for efficient PV performance. Guiavarch *et al.,* [6] also found that an air gap of 0.1 m enhanced the efficiency of PV panels as compared with the PV panels without any air gap. Summer thermal loads can also be reduced by implementing ventilated walls, facades and roofs. The combination of PV and ventilated roofs not only improves the PV transformation efficiency, but also drops the cooling load through the roofs [7]. Brinkworth *et al.* [8] found that there was a substantial increase in the electrical output of PV panels and also reduction of heat flux inside the building when air flow was induced by buoyancy in a duct behind the PV component which further reduces PV temperature up to 20K. Yang *et al.* [9] shown that the cooling-load component through a PV roof with the ventilation gap is reduced about 35% as compared with the load of a conventional roof. Mei *et al.* [10] described different behavior and found that, the cooling loads are slightly higher in case of ventilated PV façade for nearly all locations considered, whereas the impact of the façade depends critically on location in case of heating load.

The literature on the thermal performance of BIPV façade and roof system is more, but the effect of air gap behind different types of PV glazing attached over and besides the buildings on thermal load and PV efficiency has not been considered. The objective of this study is to evaluate the effect of the air gap between PV module and TW in PV-TW. Also to evaluate the effect of air gap for PV module and roof, similarly in the case of PV panel installed over the roof of the building on cooling load PV efficiency and energy consumption by using TRNSYS software. The study has been carried forward to evaluate the effect of air gap in different type PV panel's Single glass, Double glass and Double glass filled with argon, installed over the roof and wall.

METHODOLOGY

The first step in establishing a simulation predicated optimization control, is computing a dynamic model that virtually performs as an authentic building. Therefore, dynamic simulation software was needed with the ability to compute the thermal behavior of the building, with a degree of flexibility and user-graphical interface. For this reason, TRNSYS (TRaNsient SYstem

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Simulation Program) v.17 [11] was utilized. The TRNSYS software utilizes a transfer function method for simulation of the building. The model was built up starting from the case study and then transmuting parameters to elongate the results. Room integrated with PV system was simulated by changing the air gap between PV panel installed on the south side wall and over the roof for different type of PV glazing (i.e. Single glazed, evacuated double glazed and Double-glazing filled with gas).

The entire model structure done in the TRNSYS environment by taking assumption based on previous studies [12,13] that the building is a single zone room having dimensions as shown in Figure-1.

Entire TRNSYS simulation modeling was defined by 10 modules (Types). (Type 9a) data reader was installed to read the authentic weather data which was engendered as a .txt file. This data consists of the ambient temperature, irradiation and the relative sultriness that was accumulated from the weather station. (Type 69) was used to calculate cloudiness factor based on ambient conditions (temperature, humidity, and solar radiation). (Type 567-2) was installed in connection with (Type 36d) and then to (Type 56). (Type 36d) was intended to model a thermal storage wall is essentially a high capacitance solar collector directly coupled to the room.

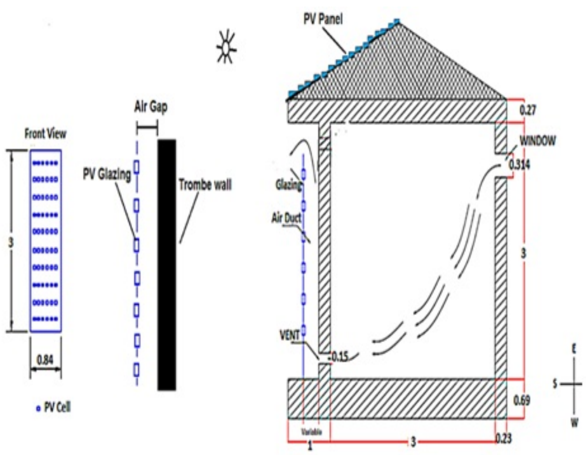

Figure-1. Schematic diagram of the test room assisted with PV-TW and PV panel over the roof.

(Type 56) is intended to model a thermal behavior of a building having multiple thermal zones. (Type 25) is a printer component used to output (or print) culled system variables at designated intervals of time. (Type 642) models a fan that is utilized to vary the air flow velocity.

RESULTS AND DISCUSSION

Effect of air gap on PV efficiency

Effect of air gap for different type of PV glazing, which were Single glass, Double glass and Double glass filled with Argon, were analyzed and the outcome of the analysis has been shown in Figure-2, 3 and 4, respectively. It was found that in case of PV panel attached on the wall as PV-TW arrangement, maximum PV efficiency was achieved in the case of Double glass filled with Argon PV-TW at an air gap of 0.2 m. The result of the analysis has been compared with Yang et.al [14] results and presented in Figure 6. Also that about 50-57% PV efficiency is enhanced by using double glass filled with argon PV panels with air gap as compared to normal glass PV panels without air gap. Analysis shows that as the air gap increase from 0.05 m to 0.175m, PV efficiency increases. This was mainly due to the relatively higher flow resistance provided by the smaller air gap as compared to larger air gap. Air flow rate is the product of the air gap and air velocity, would be much lower for thinner air gap which leads to increase in the temperature (mean and maximum) of cell.

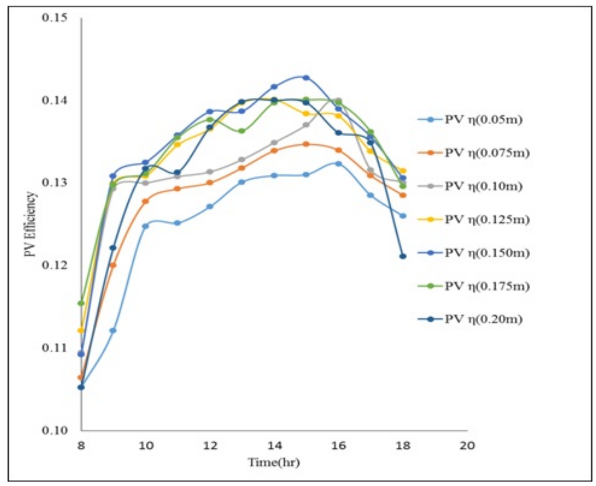

Figure-2. Effect of air gap behind Single glass PV-TW on PV efficiency.

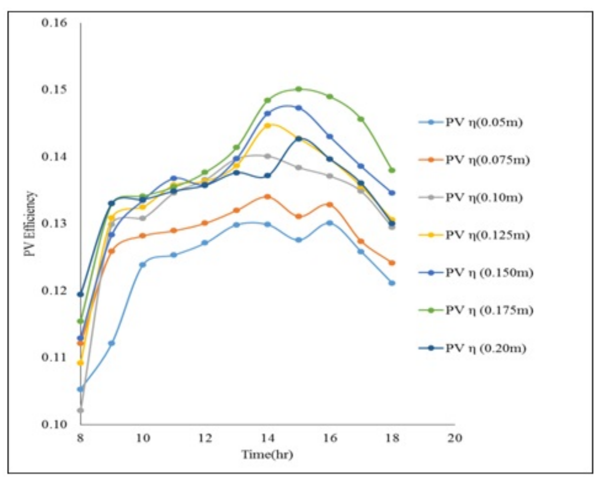

Figure-3. Effect of air gap behind double glass PV-TW on PV efficiency.

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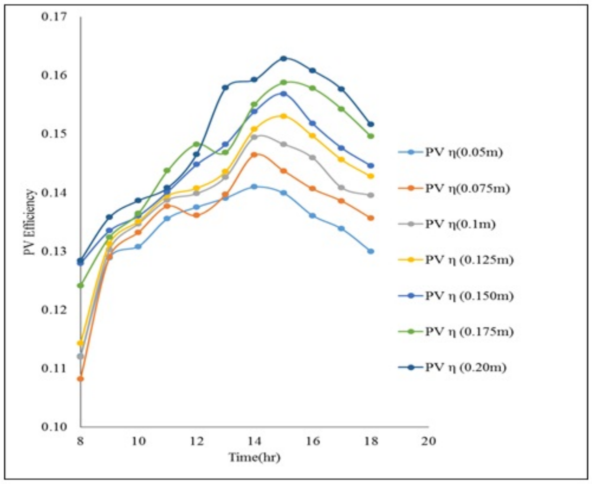

Figure-4. Effect of air gap behind double glass filled with argon PV-TW on PV efficiency.

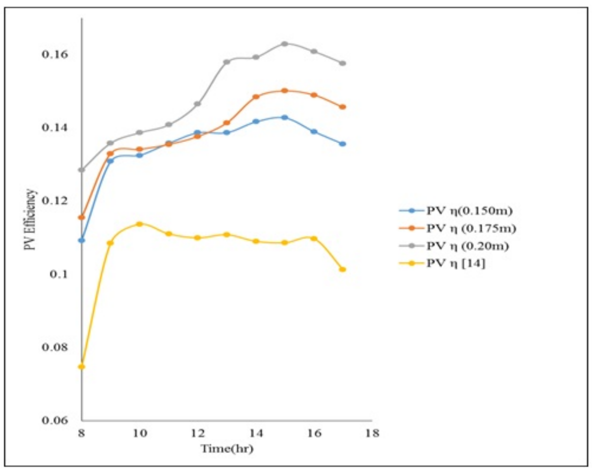

Figure-5. Comparison of PV efficiency of different glazing with previous study.

This was in agreement with the results published by other researchers [15]. It also shows that, in case of single glass and double glass PV-TW beyond 0.175 m air gap effect stagnates and PV efficiency remain same for further increase in air gap and minimum or critical air gap that is required to minimize overheating of PV devices was lying in the range of 0.11 to 0.14 m for three different types of PV-TW.

Efficiency of PV panel attached over the roof depend on two factors, i.e. air gap and pitch angle [16]. Effect of roof pitch angle on PV efficiency for three different types of glazing at fixed air gap (i.e. 0.150m for single glass, 0.175m for double glass and 0.2m for double glass filled with argon) and fixed time (i.e. weather condition data of 1 pm to 3 pm) was shown in Figure-6.

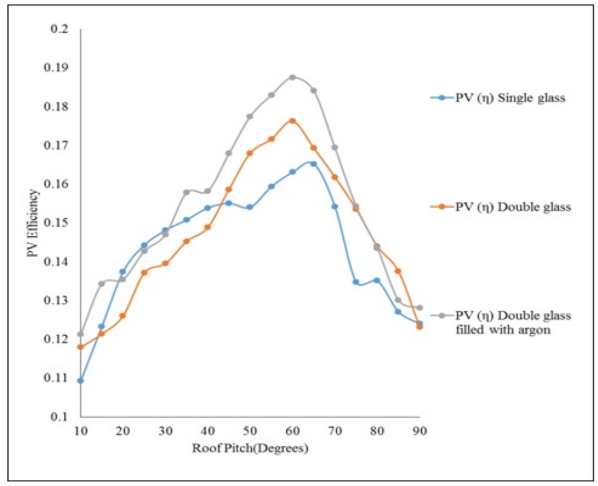

Figure-6. Effect of roof pitch angle on.PV efficiency by varying glazing type.

It is easy inferred from Figure-6, that means velocity in the air gap increases with the increase in the air gap and pitch angle, as it removes the accumulated heat inside the gap and reduce the PV cell temperature the same results are obtained are also shown by [17]. The mean and maximum PV temperature decreases with the increase in pitch angle which is 7 degrees to 17 degrees in case of single glass PV panel, 8 degrees to 21 degrees in case of the double glass PV panel and 12 degrees to 20 degrees in case of double glass filled with argon PV panel. The PV temperature will increase with further increase in pitch angles for all the three cases described above. This was mainly due to the reduction in mean velocity inside the air gap after attaining certain critical pitch angle, which further delays the heat transfer rate which results in increase in PV cell temperature.

Effect of air gap on cooling load

The effect of air gap on cooling load has been analyzed for the three different PV glazing which were Single glass, Double glass and Double glass filled with Argon PV-TW and presented in Figure-7, 8 and 9, respectively. It was found that in case of PV panel installed over the wall as PV-TW, cooling load in all the three type of PV glazing first decrease and then increases in the presence of sun light and finally decreases in the night time. This behavior is due to heat wave propagation from outside surface (i.e PV panel) to the inner surface of the wall which requires time or called as time lag [18]. The simulated results show that among all the three cases Double glass filled with argon PV-TW shows highest reduction in cooling load at an air gap 0.2m. Double glass PV-TW also shows significant reduction in cooling load at air gap ranging between 0.175m to 0.2 m, which is 18% less than Double glass filled with argon PV-TW at the same air gap range. By comparing the cooling load characteristics all the three different types of PV-TW, it was found that ventilated double glass filled with argon provide more insulation towards heat penetration, so the

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amount of heat penetrated inside the building get reduce. Also, it was found that after reaching the air gap above 0.2m, effect of air gap on cooling load stagnates and no further improvement was shown in all the three cases.

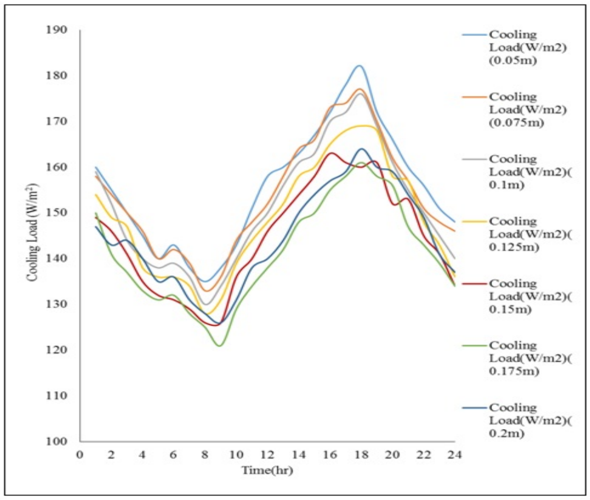

Figure-7. Effect of Single glass PV-TW on cooling load for different air gap.

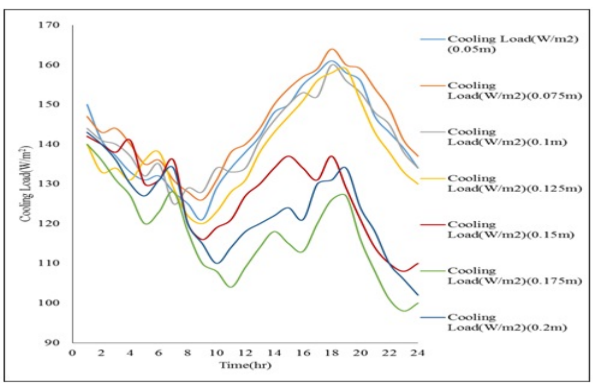

Figure-8. Effect of Double glass PV-TW on cooling load for different air gap.

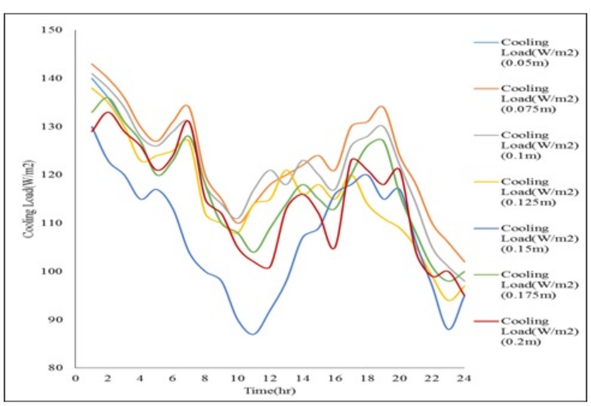

Figure-9. Effect of double glass filled with argon PV TW on cooling load for different air gap.

Yang et.al [14] experimentally found that PV-TW reduces 33%-50% cooling load of building as compared to normal buildings. Also Ji et.al [19] experimentally found that the temperature difference between the room with and without PV-TW reaches maximum up to 12.3 °C. Other researchers also shown that ventilated PV-TW has a significant effect on cooling load of the building [20,14].

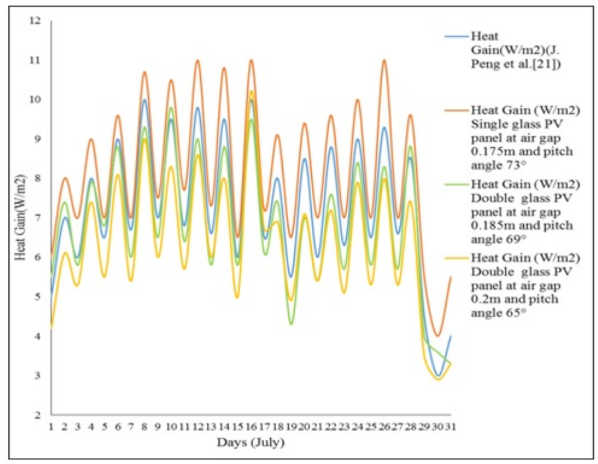

Figure-10. Heat gain comparison of the PV panel installed over and beside the building with previous study in July.

By comparing our results with J. Peng et. al. [21] results in Figure-10, it can be inferred that the maximum heat gain reduction is achieved in case of double glass filled with argon PV panel at air gap 0.2 m and pitch angle 20 degree. The annual heat transfer variation with air gap for Malaysian climate was presented in Figure 13, it was found that the optimized value of air gap was 0.150 m for single glass PV-TW, 0.175 m for double glass PV-TW and 0.2 m for double glass filled with argon PV-TW but for Hong Kong climate critical air gap of the south facing PV wall is only 0.06 m [21].

Effect of air gap on carbon dioxide (CO_2) emission

The effect of retrofitting of building with PV-TW and changing glazing type and air gap behind PV panels shown considerable amount reduction in atmospheric CO_2 emissions released by a power plant. A normal CO_2 equivalent intensity for power generation from coal is more or less 0.98 kg of CO_2/kwh [22]. Hence, the reduction in CO_2 emissions into the atmosphere by energy conservation due to retrofit is 1287 kg/year in case of single glass PV-TW and 1818 kg/yr in case of double glass PV-TW and 2634 kg/yr in case of double glass filled with argon PV-TW. Also Jaber et.al [23] experimentally shown that TW save 445 kg of CO_2 annually for Mediterranean climates. Chel el. al [12] also found that about 33 tonne/yr of CO_2 emission was reduced by retrofitting the building with TW for Gwalior (latitude: 26°14′N) in India.

CONCLUSIONS

The effect of air gap behind PV panel installed over the roof and wall as PV-TW has been analyzed by using simulation software TRNSYS v.17. It was concluded that

- As the air gap increase from 0.05 m to 0.175m, PV efficiency increases and energy consumption decrease.
- Maximum PV efficiency and minimum energy consumption were achieved in the case of Double glass filled with Argon PV-TW at air gap of 0.2 m as compared to single glass and double glass PV-TW.
- It was also found that in case of single glass and double glass PV-TW beyond 0.175 m air gap effect stagnates and PV efficiency will remain same for further increase in the air gap.
- Efficiency of PV panel attached over the roof depends upon the means velocity in the air gap which increases with the increase in the air gap and pitch angle. The mean and maximum PV temperature decreases with the increase in pitch angle up to a certain critical angle which is different for different glazing.
- It was also found that maximum energy consumption reduction was achieved in the case of Double glass filled with Argon PV-TW at air gap of 0.2 m.
- Cooling load characteristics results shows that among all the three cases Double glass filled with argon PV-TW shows highest reduction in cooling load at air gap 0.2m. It was also found that cooling load of building reduce up to 44-52% by implementing ventilated double glass filled with argon PV panel over and beside a building envelope as compared to normal houses.

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