Investigation of indirect benefits of PV rooftop in Thailand

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Abstract. Other than electricity generation, which is the direct benefit of PV rooftop, cooling load reduction due to PV shading is a benefit impact in the uses of PV rooftop. This report is a study of those indirect benefits of PV rooftop. Relation of shading of PV modules and reduction of cooling load was studied in a real testing cite at the office building of CES Solar Cell Testing Center (CSSC). Several data, i.e. solar radiation, rooftop temperatures before/after PV-panel installation, and electricity consumed by equipment, were monitored and collected. This data could be further estimated for cooling load via transient heat conduction approach.

1. Introduction
Electricity is one of the major important things to all human living and it is a primary factor for country development. Since, it plays significant roles in both economic and community sectors. Moreover, it helps to encourage agricultural products, industrial products, and public service parts.

In the last decades, population growth has been significantly increased but production of electricity would be insufficient to the energy consumption in Thailand. Therefore, Thailand has to find sufficient primary energy sources for electricity production. However, due to inefficient energy production technologies and energy management plans, Thai government requires huge amount of natural resources, i.e. crude oil, diesel, natural gas, and coal [1]. In addition, Thai government is also buying more electricity from Malaysia and Laos to support domestic energy demands [2-4].

In fact, if we have no a good management plan, our reserved energy will be terminated in the near future. Energy-statistic data of Thailand in 2014 showed the continuous increase of overall energy consumption. The highest electricity has spent by the household, which is mainly from the air-conditioning system. The way to reduce this electricity cause is reduction of the cooling load the building. One strategy to reduce the cooling load is decrease of heat gain from solar radiation absorbed on the rooftop. Since the rooftop directly receives heat during daytime. If there is no proper prevention, cooling load of air-conditioner will increase and cause more expenses to the resident in the future.

From previous studies, there are various methods to reduce heat gain passing through the rooftop to the building. One of interesting method is the uses of solar PV panel as shading devices. Moreover, solar energy is a suitable energy resource and shows potential to support other renewable technologies in Thailand, such as wind or hydroelectric powers, because Thailand is geographically located at the position with a high level of solar insolation. Moreover, the cost of PV-system installation is relatively low and panels are relatively visually unobtrusive compared with other renewable energy solutions such as wind power turbines [4]. Therefore, Thailand Ministry of Energy established a new Feed in
Tariff Program for solar PV rooftops [5-7] to provide incentives and draw more intention of people on PV system. This new solar policy aimed to support new capacity of 1,000 MW (200 MW for rooftop projects and 800 MW for community projects). New (fixed) feed in tariffs was specified. For the rooftop projects FiT was set at 6.16-6.96 THB (depending on size). For community projects (>1 MW), FiT was set for (1) an initial value of 9.75 THB, (2) 6.5 THB after the 4th year, and (3) 4.5 THB during the 11th year and the 25th year [8-9].

Not only decrease of the heat gain flows into the building using PV panels as a shading device as mentioned above. Solar rooftop also has other benefits (or indirect benefits). Firstly, the expense of resident can be reduced by use of electricity from solar PV instead of that from electricity grids. Secondly, it helps to promote the energy and environment preservation and reduction of the climate change problem. Lastly, it educates the good energy and environmental attitudes to all family members and community that use solar rooftops.

As mention above, the residential solar rooftop market in Thailand is new and needs further marketing and support for future growth. Therefore, this research aims to investigate an indirect benefit, i.e. reduction of heat gain to building, of PV rooftop in Thailand in details.

2. Experimental setup

2.1. Testing site building and location

The building used in this study was a model room of CSSC building at the King Mongkut’s University of Technology Thonburi (KMUTT). The simulation images of the building are shown in figure 1. The building was made from lightweight concrete (thick = 0.1 m) with a roof area of 126 m² made from roof tiles (CPAC Monier). Solar PV panels used in this work were amorphous silicon cells (54W) purchased from Kaneka (Japan) with the size of 996 mm x 999 mm. The panels (14 panels) were mouthed horizontally with the roof surface in 4 groups (4, 4, 4, and 2 panels) (Fig. 1).

There were 9 windows placed around the building. This building contains 2 sections, office and toilet zones. The office zone was located at the front (facing to the North), while the toilet zone was located behind the building (facing to South). The office section was divided into air conditioning and un-conditioning zones. On workdays, the building was cooled by the air-conditioning system. For the toilet, it was made of hollow-lightweight concrete cube without any air conditioning system (it was cooled by natural ventilation through the gate and windows around the building).

![Figure 1. Model of CSSC building (facing to North) with 14 PV panels (4, 4, 4, and 2 panels in 4 groups) created by SketchUp Program: (a) eagle-eye and (b) side views.](image)

2.2. Data monitoring and collections

Data monitoring was carried out in 3 sections; on the rooftop, the loft under PV panels (which directly received shading from PV panels), and the conditioning zone (office). The details are in Fig. 2.
3. Results and discussion

3.1. Benefits of PV rooftops (reduction of heat gain)

Figure 3 shows inner surface temperature of the roof, outer surface temperature of the roof, outdoor dry-bulb temperature, and air temperature above ceiling measured in both a room without any PV panel (exposed roof) and (b) a room with PV panels. It was found that when the model room exposed to sunlight, the outer surface temperature of the west-facing roof (measurement points 1 in figures 2(a) and 2(b) showed a peak at noon and always higher than the outdoor dry-bulb temperature (measurement point 3 in figures 2(a) and 2(b) and the air above ceiling temperature (measurement point 4 in figures 2(a) and 2(b)) during daylight hours. However, the outer surface temperature was lower than the outdoor dry-bulb and air above the ceiling temperature during the night.
Figure 3. Inner surface temperature of the roof (West side), outer surface temperature of the roof (West side), outdoor dry-bulb temperature, and air temperature above ceiling measured in both (a) a room without any PV panel (exposed roof) and (b) a room with PV panels.

For the exposed roof (no PV panel), the outer surfaces of roof (point 1 in figure 2(b)) were heated by solar radiation, then the heat could transfer to the inner surface (under the roof, point 2 in figure 2(b)). Since the air can move on the outer surface, so the outer surface was cooler than the unventilated under surface (in the loft, the air was trapped, so it heated the inner surface up). This situation also occurred in the case of the room with PV panels. The temperatures under the PV arrays (roof with PV shading) (measurement points 1, 2, and 4 in figure 2(b)) was significantly lower than that of the exposed roof (measurement point 1, 2 and 4 in figure 2(a)). This is because surface temperature of the exposed roof was heated directly by the strong solar irradiance [9, 10]. However, under the PV arrays was shaded by the panels. So, it was not heated by the solar radiation, but only long wavelength radiation (lower energy) under the panels and weak diffuse radiation from the sky. The sum of these radiations are less than the solar irradiance from the exposed roof [9].

3.2. Thermal infrared camera
Sections A thermal infrared (TIR) image was use the confirm the temperature difference in the case of use of PV rooftop. Figure 4 demonstrated that roof surface temperatures under the PV arrays were lower than the directly exposed roof (up to 9 °C) at 1200 PST. As illustrated in figure 4, a cool area under the PV panels was obviously observed. This observed result was in line with the actual situation explained above.
Figure 4. A thermal IR camera image of outer roof surface (measurement point 1 in figure 2) taken at 1200 PST on September 30, 2016. The color bar denotes temperatures in °C.

4. Conclusion
This study demonstrates that PV panels as building shading serve as a potential solution for the reduction of heat pass through the roof to the building in the hot climate days. All results could be considered as an estimation of PV benefits for the PV-panel equipped building. The model in this works can be use further to calculate for energy saving improvements. This data can be further estimated for cooling load via transient heat conduction approach. The electricity generation and reduction of building cooling load by shading of PV system in a bigger image (covered the recently announced solar energy policy of Thailand) should be further investigated.

5. References
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