THE ANALYSIS OF SOLAR POWER SYSTEM GENERATION FOR DIFFERENT BUILDING ORIENTATION

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ABSTRACT

The amount of solar energy absorbed by a photovoltaic (PV) panel could be affected by the orientation of the panel with respect to the sun. It is one of the important criteria that need to be considered in order to obtain more output power from the solar energy system installed in a building. The objective of the research is to understand whether the orientation of the solar panel would affect the production of electrical energy generated from the sun. Another criterion that we study is the weather condition. In order to study the effect of building orientation with respect to the efficiency of the solar panel, the weather condition needs to be factored in as it could affect the result of the study. Thus, in order to get valid results, the experiments were done repeatedly not only during sunny days but also during cloudy days. This research paper also evaluates the cost comparison between installing solar energy systems in a building and the cost of paying the electricity bills to the local utility provider.

Keywords: Renewable Energy; Building Orientation; Solar Energy; Efficiency; Cost Comparison

INTRODUCTION

Nowadays, a non-renewable energy sources are declining while our energy demands continue to increase. Based on the research conducted, while the demand is increasing, the cost of the raw materials of the non-renewable energy sources such as coal and oil also increase and become expensive. Thus, this problem has burdened the consumer. Besides that, since the demand still continues to rise, ultimately the energy sources will be exhausted in the future. This has made the world concern that an effective solution for an alternative energy sources is vital to be found. Thus, efficiency is a dilemma in this context.

In order to overcome this problem, the renewable energy sources which means that energy generated from natural resources such as sunlight, wind, rain, tides and geothermal heat which are renewable (naturally replenished) are highly needed. This type of energy will never run out and constantly can be renewed.

In Malaysia, almost all of the buildings are using electricity from the non-renewable energy supplied by the Tenaga National Berhad (TNB). The burning of fossil fuels that they are using, at the same time, produces greenhouse gases that will affect the environment which leads to the global warming and acid rain.

Solar energy in a building has practically been used in other countries such as China and Canada. Nowadays, Malaysia is moving towards the solar energy deployment in a building. This move by the government is proven base on the implementation of the Malaysia Building Integrated Photovoltaic (MBIPV) Program. The solar energy is environmental friendly and by using this type of energy, this country can reduce the air pollution produced by the fossil fuels that can lead to the global warming.

In Malaysia, the weather or climatic conditions are favorable to the development of solar energy with abundant sunshine throughout the year. In order to fully utilize the solar energy absorption, the orientation of the solar panels should be coordinated with the solar movement. This means that in Malaysia the sun will rise from the East and sunset at the West. Thus, in order to get maximum solar exposure for solar collection, building orientation will be studied in this research. Through this orientation of a building, the solar collecting system will absorb maximum solar heat or radiance to be store in the battery bank.

METHODOLOGY

The content of this chapter will cover the processes and methods of the research that have been used throughout the studies. The orientation of the building or solar panel will be the main objective for this project because it will provide the vital information regarding the efficiency of the solar panel based on the orientation.

Initially, to study the effect of the orientation with respect to the efficiency of energy produced, the basic concept of solar panel working principle needs to be observed. This will explain on how the solar system functions. Basically, the solar panel will convert the energy form the sunlight that hits on the solar panel to electricity – in the form of DC supply. Then, this electrical energy will be sent to the charge controller. After that, the inverter will convert the DC supply from the solar panel to AC supply which can be used directly in the building. Figure 1 shows the solar panel (solar energy system) working principle process flow.

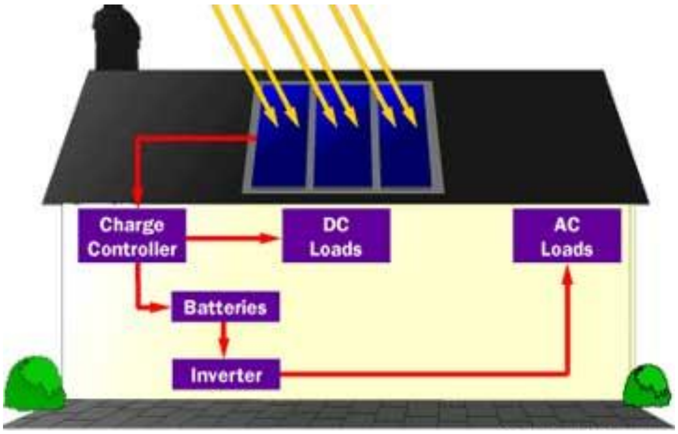

Figure 1: Solar Panel Working Principle Process Flow

Energy efficient in a building (new constructions or renovated existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipment that will be chosen to heat or cool the building. The energy efficiency can be described as an output energy efficient when it can produce more energy or same energy as the building or equipments required for less energy input. There are few factors that play as an important roles in the energy efficient building such as photovoltaic system, integrated building, and also the orientation of the building (solar panel).

Based on the factors that will affect the energy efficient management in the building, the orientation of the building is one of the main factors that will effect the energy efficiency. Thus, to produce the highest efficiency of solar energy absorption from the solar panel, a prototype of a building with the solar panel installed is created to obtain the actual data based on the orientation. Figure 2 shows the 12 V solar panel with the power output of 10 W. On the other hand, Figure 3 shows the charge controller where it will help the solar panel to produce a consistent output data that will be used as a result for the experiment. It also prevents the battery from overcharging and protect against overvoltage problem. A battery, as shown in Figure 4 will be used as an energy collector as the electricity produced from the solar panel will be stored directly in the battery.

Tools and Equipment

Figure 2: Solar panel used for the experiment

Figure 3: Charge controller for controlling and reading of the experimental results

Figure 4: Battery for solar power storage and supply for the charge controller

RESULT AND DISCUSSION

Solar Orientation Experiment

Figure 5: Setting of solar panel for the experiment

Figure 5 shows the solar panel that is used to give different orientation of the building. The angle of the solar panel is 40 degrees with respect to the prototype building. This is chosen since normal building roof angles deviate from 40 to 45 degrees. The building is oriented to face the East, West, North, and South poles. From this experiment, the output data for all of the orientation are then compared.

Table 1: Power output on west side

Time (Hour)	Temperature (Celsius)	Voltage (V)	Ampere (A)	Power (Watt)
10.00 a.m.	39	20.4	0.2	4.08
11.00 a.m.	39	20.6	0.1	2.06
12.00 p.m.	42	20.8	0.2	4.16
1.00 p.m.	43	20.8	0.3	6.24
2.00 p.m.	40	20.9	0.3	6.27
3.00 p.m.	41	20.5	0.3	6.15
4.00 p.m.	42	20.4	0.3	6.12
5.00 p.m.	41	19.8	0.2	3.96

Efficiency on the West Side

$$\text{Efficiency} = \frac{39.04}{80.00} \times 100\% = \mathbf{48.8\ \%}$$

Table 2: Power output on East side

Time (Hour)	Temperature (Celsius)	Voltage (V)	Ampere (A)	Power (Watt)
10.00 a.m.	40	21.3	0.3	6.39
11.00 a.m.	40	21.5	0.4	8.60
12.00 p.m.	43	21.7	0.3	6.51
1.00 p.m.	42	20.5	0.3	6.15
2.00 p.m.	42	20.3	0.3	6.09
3.00 p.m.	42	20.0	0.2	4.00
4.00 p.m.	41	19.9	0.2	3.98
5.00 p.m.	41	19.5	0.1	1.95

Efficiency on the East Side

$$\text{Efficiency} = \frac{43.67}{80.00} \times 100\% = \mathbf{54.59\ \%}$$

Table 3: Power output on North side

Time (Hour)	Temperature (Celsius)	Voltage (V)	Ampere (A)	Power (Watt)
10.00 a.m.	39	20.7	0.0	0.00
11.00 a.m.	40	20.7	0.1	2.07
12.00 p.m.	42	20.8	0.2	4.16
1.00 p.m.	42	20.6	0.3	6.18
2.00 p.m.	42	20.6	0.2	4.12
3.00 p.m.	40	19.9	0.2	3.98
4.00 p.m.	41	20.3	0.1	2.03
5.00 p.m.	41	20.0	0.0	0.00

Efficiency on the North Side

$$\text{Efficiency} = \frac{22.54}{80.00} \times 100\% = \mathbf{28.18\ \%}$$

Table 4: Power output on South side

Time (Hour)	Temperature (Celsius)	Voltage (V)	Ampere (A)	Power (Watt)
10.00 a.m.	40	20.2	0.1	2.02
11.00 a.m.	40	19.9	0.2	3.98
12.00 p.m.	42	20.4	0.3	6.12
1.00 p.m.	42	20.4	0.3	6.12
2.00 p.m.	43	20.8	0.2	4.16
3.00 p.m.	42	20.9	0.2	4.18
4.00 p.m.	41	20.4	0.2	4.08
5.00 p.m.	40	19.8	0.0	0.00

Efficiency on the South Side

$$\text{Efficiency} = \frac{30.66}{80.00} \times 100\% = \mathbf{38.33\ \%}$$

The results are as shown in Table 1 to Table 4. The efficiency for all different building orientations is then calculated such as 48.80% for the West side, 54.59% for the East side, 28.18% for the North side and 38.33% for the South side.

From Table 1 to Table 4, the output power of the solar energy is shown for every hour during the experiment. In order to see the influence of the orientation of the solar panel towards the solar energy absorption, a graph is plotted to show different value of the energy with respect to building orientation and time. Figure 6 shows the comparison of output power against time for all building orientation.

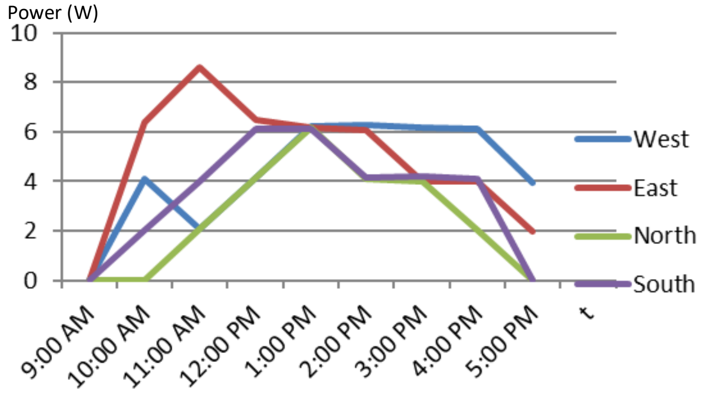

Figure 6: Graph of output power versus time for the different building orientation

COST ANALYSIS

One of the main issues that the consumer concerned about the installation of solar system is the return on investment of installing the solar energy system in a building. The cost of the installation of the solar system is quite high. In addition, nowadays the consumer would not generate any income from the system by claiming the Feed-in Tariff (FIT) program. This is because the FIT program is suspended by the government. Thus, in order to calculate the profitability of installing the system versus using the TNB supply, calculation is made to compare the cost of the solar system installation against the monthly TNB bills of a building. In order to do this, an anonymous building is chosen to get the TNB bills for the monthly electricity consumption.

Based on the bills collected from the building, the latest bill (December 2014) is used as a reference for the energy usage per month. In general, the energy consumption of the building was almost the same for the past 3 months (from the month of October until December). The total energy usage for December 2014 is 978 kWh/month.

The energy output from the solar panel is also calculated to make this comparison as follows:

Total energy per day = $\frac{978 \text{kwh/month}}{30 \text{ days}}$ = 32.60 kWh/day

Energy use in an hour = $\frac{32.6 \text{ kwh}}{24 \text{ h}}$ = 1.36 kW

Therefore, the building needs approximately 2 kW per hour to support the daily energy amount that the building requires for operation. Thus, the solar panel that is recommended for the building is of the 4.7 kW type. The efficiency of the solar panel is rated at 10-15% of energy losses. Thus:

The Photovoltaic absorption (kW) = 0.9 x 4.7 kW = 4.23 kW

Total power generate per hour = 4.23 kW x 1 hour = 4.23 kWH

Total energy that the PV produce per day = 4.23 kW x 11 hour = 46.53 kWH/day

The value of energy that the solar panel collected per day is 46.53 kWH/day because the PV can only be used for 11 hours per day. This is because the PV system can only generate electricity during the day time. Thus, the 11 hours per day is based on the working hours of the building. The cost of the electricity bills for the month of December is RM478.50. In order to compare with the cost of the installation of the solar system, we assume that for 28 years there is no additional cost. This is because we assume that the only cost involve is a one-time installation cost. Therefore, calculation of this comparison is as follows:

Total bills per year
= RM478.50 x 12 months
= RM5,742.00 per year

The cost of current system for 28 years
= RM5,742 x 28 years
= RM160,776

Based on the cost calculated, the cost of the fossil fuels for another 28 years is RM160,776 whilst the one-time installation cost of the solar system for the building requirement is RM90,000. The instalment of the solar panel installation is

RM1071.43 per month if loan were taken. Figure 4.3 shows the graph for cost of the system against the time period which is 28 years.

Profit = RM160, 776 – RM90,000 = RM70,776

The efficiency in term of cost saving (profit):

Efficiency = $\frac{70776}{160776} \times 100$ = 44.02%

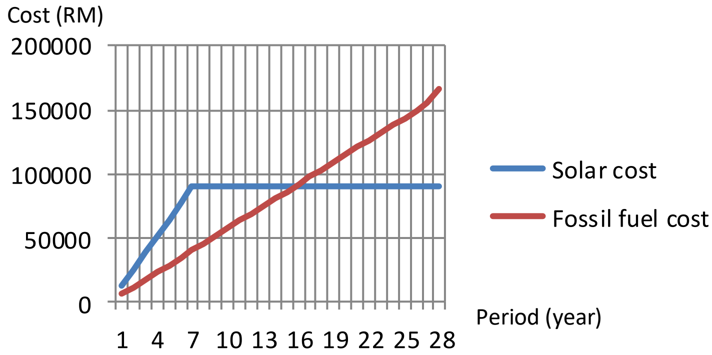

Figure 4.3: Graph Cost (RM) against Period (year)

This experiment was carried out for the purpose of studying the orientation of the building with respect to solar energy efficiency and understanding of the cost involved in solar system installation versus getting electricity supply from the local utility provider. The objective of this research has now been met.

CONCLUSION

This research highlighted the efficiency of a solar panel based on the orientation of a building. After a few weeks of collecting and examining the data, the result obtained shows that the orientation of a building or solar panel affects the absorption of an energy capacity in the solar panel. This proves that the environmental condition also affect the solar panel efficiency. This is because the solar panel needs more direct sunlight to produce greater amount of electrical energy.

Based on the result obtained, a basic concept of the solar panel and its working condition were observed through the experiment. The experiment also helps to prove and provide better information about the building orientation and also the effect of rain and clouds towards the energy absorption. This is one of the criteria that play an important role in the building orientation experiment. In order to achieve the research objective, the experiment has to be conducted in a suitable weather condition as it will affect the data collection.

From the experiment, the efficiency of the solar panel will be affected when the weather is cloudy. In a cloudy day, the data obtained is not relevant as the clouds block the sunlight. Basically, the nonlinearity of the research data is because of a cloudy day. Thus, to get a reading from the charge controller, the researcher needs to wait for about 3 minutes under the sun to collect the average value that is shown on the solar system monitor screen.

In order to compare the efficiency of an energy consumption and cost, the experiment is done by surveying a suitable building, studying the efficiency of the solar panel, and having different building orientation. Then the data then were compared and calculated to get the cost comparison and return on investment of the installation.

From this research, although the one-time installation cost of the solar system is huge, in the long run, consumer would enjoy the benefit of a free energy from the solar system. This is proven from the cost comparison which shows that the ROI of the solar system is seven years, and the consumer can start to use the free energy for another 20 years afterwards.

RECOMMENDATION

Based on the research conducted for the solar system, we found out that the orientation of the building will affect the efficiency of the solar panels. As a result, it shows some limitation regarding the movement of the solar panel and how to improve the efficiency of the solar panel based on their movement – in order to increase the output power of the solar system. Thus, future research can focus on the following recommendations in order to improve the efficiency of the solar panel:

i. Install the Solar Tracking System: This system would help to increase the output power of the solar panels by rotating the panels directly towards the sun. There are many types of solar tracker. This can be an automatic tracker (movement of tracker based on programming) or tracker that is simply driven by a clock motor.

ii. Install the Maximum Power Point Tracking: This system simply increase the charge current so that of the power output of solar panel is 10 W. The battery can actually be charged at a higher level.

iii. Use different type of solar panel: There are few types of PV panel such as crystalline silicon, mono-crystalline silicon, polycrystalline silicone, thin film solar cells, and any other more efficient building-integrated photovoltaic cells.

REFERENCES

[1] Parekh, V. "Passive Solar Building", International Journal of Applied Engineering Research, vol. 9(3), pp. 351-356, 2014.

[2] Azhari, A. W., Sopian, K., Zaharim, A., & Al Ghoul, M. "A New Approach for Predicting Solar Radiation in Tropical Environment using Satellite Images–Case Study of Malaysia", WSEAS Transactions on Environment and Development, vol. 4(4), pp. 373-378, 2008.

[3] Robertson, K. & Athienitis, A. "Solar energy for buildings", 2009.

[4] Kiss, B. "Building Energy Efficiency-Policy", Learning and Technology Change (Doctoral Dissertation, Lund University), 2013.

[5] Mekhilef, S., Saidur, R., & Kamalisarvestani, M. "Effect of Dust, Humidity and Air Velocity on Efficiency of Photovoltaic Cells", Renewable and Sustainable Energy Reviews, vol. 16(5), pp. 2920-2925, 2012.

[6] Rathod D., Khandare R. & Pandey A. K. "Electrical Energy Audit (A Case Study of Tobbaco Industry)", International Journal of Engineering, vol. 2(3), pp. 2305-8269, 2013.

[7] Kumar S. & Kaur T. "Energy Audit: A Case Study", International Journal of Research in Management, Science & Technology, vol.1, pp. 2321-3264, 2013.

[8] Avina, J., & Reshat, E. "Eight Ways in Which a Poor Quality Energy Audit Can Prove Costly to The Building Owner", Energy Engineering, vol 110(4), pp. 64-75, 2013.

[9] The Latest Tenaga Nasional Berhad (TNB) Pricing and Tariff. Retrieved November 15, from TNB Official Websites: http://www.tnb.com.my/ residential/pricing-and-tariff.html