

Analysis Simulation of the Photovoltaic Output Performance

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Abstract--Solar photovoltaic (PV) power generation is an attractive technique to reduce consumption of fossil fuels and as a renewable energy. PV system is convert photo energy into direct-current energy. The temperature of PV modules increases when it absorbs solar radiation, causing a decrease in efficiency. The overall power output and efficiency of the PV module can decrease by $\sim 0.5\%/^{\circ}\text{C}$ and $\sim 0.05\%/^{\circ}\text{C}$ when the ambient temperature of module increases. In fact the efficiency of the general PV modules is only between 13% until 20%. This caused will affected the PV module lifespan. In this work, the performance of PV output power is analysis by using PVsyst software. The open-circuit voltage (V_{oc}) of PV module, short circuit current (I_{sc}) and every change temperature on PV module are measure and record. In this work, the result of efficiency of PV under cooling system is 14% while the efficiency of PV under without cooling system is 10.3%. The incident irradiance is 1000 W/m^2 , the efficiency of PV module is 13.05% while the incident irradiance is 200 W/m^2 , and the efficiency of PV module is 10.45%. The higher efficiency of PV cell, the payback period of the system can be shorted and the lifespan of PV module can also be longer.

Keywords- Photovoltaic (PV); temperature; incident irradiance; PVsyst; conversion efficiency

I. INTRODUCTION

In all over the world, energy plays an important role in human society. The energy is dividing into two types which are conventional energy and non-conventional energy. As the result of world economic development and growing demand for energy, the conventional energy (coal, oil and natural gas) is rapidly increasing. Environmental phenomenon, such as global warming and depletion of the ozone layer attributed to emissions from massive fuel combustion are slowly but surely causing widespread problems to every living thing on earth [1]. Thus, it is important to explode non-conventional energy to replace conventional energy sources. Non-conventional energy also called as renewable energy such

as solar energy, biomass energy, tidal wave energy, wind energy, hydropower, and so on. When the renewable energies become famous in the energy market, the demand of conventional energy will be reduced. Beside that renewable energies are suggested to provide a solution to resolve problem of global warming in the world.

Photovoltaic energy is a source of interesting energy; it is renewable, inexhaustible and non-polluting, and it is more and more intensively used as energy sources in various applications [2]. PV technology is any one very effective solution among renewable energies and is unpolluted natural resources. Earth receives quantity of solar irradiation from sun is more than the consumption of humans need. The PV system is silent and environmentally friendly as it will to reduce greenhouse emission. PV system is convert solar radiation into electrical energy through solar cells. The basic material of the PV cell is semiconductor such as silicon (Si). A silicon module consists of a series circuit 36 cells. Basically, three types of technology are used in the production of photovoltaic cells: monocrystalline; polycrystalline; and amorphous silicon [3]. The conversion efficiencies (efficiencies of solar energy to electrical energy) for monocrystalline are in the range of 12% - 20%. While the range of conversion efficiencies for polycrystalline are in 10% - 18% and the conversion efficiencies for amorphous is in the range of 6% - 9%.

The efficiency of the PV cell is affected by the operating temperature and incident irradiance. As the operating temperature of PV module increases, the efficiency of PV module decreases and vice versa. As the incident irradiance of PV module is stronger, the efficiency of PV module increases. The higher efficiency of PV module, the payback period of the system can be shorted and the lifespan of PV module can also be longer. The general rule of this decrease is determined first of all by the voltage drop of open circuit cells. Thus, an

efficient PV performance conditions required cooling. During PV modules operate in the outdoor; the PV module suffers high irradiation conditions when reached at high temperatures.

Temperature coefficient has been presented few different PV performance parameters such as voltage, current and power. The effect of temperature on a PV module in relation to the standard test condition (STC) is determined by using temperature coefficients. The manufacturers of PV modules provided general reference values for specified operating condition such as STC (Standard Test Conditions) for which the irradiance level is 1000 W/m^2 and the cell temperature is 25°C . Real operating conditions are always different from the standard conditions, and mismatch effects can also affect the real values of these mean parameters [4]. The rate of change of temperature coefficient related to temperature of different of photovoltaic performance parameters. The rate of change can be determined for short-circuit current (I_{sc}), maximum power current (I_{pm}), open-circuit voltage (V_{oc}), maximum power voltage (V_{pm}), maximum power (P_m), fill factor (FF) and efficiency (η). When the temperature increase, V_{oc} will decrease at a rate of $0.1\%/^\circ\text{C}$ whereas I_{sc} increases slightly with temperature (T). FF also decreases all these lead to an overall decrease in the cell efficiency [5].

Only around 15% of solar radiation is converted to electricity [6]. The temperature of the module increases, most solar radiation absorbed by PV modules is converted into heat due to the low conversion efficiency of PV modules. Indeed, the conversion efficiency of the PV modules is decreased by about 0.4–0.5% per each degree rise in temperature [7]. The decreasing rate of temperature effect in electrical efficiency was also found to be $0.1\%/^\circ\text{C}$ [8]. Thus, cooling system of PV modules is essential important to increase efficiency in PV system.

Kozak et al. [8] presented a study of temperature variation of the water cooled PV solar template where the system included the heat exchanger mathematical module has been established and the variation of template temperature with the amount of cooling water has been calculated and analyzed under the different power and the inlet water temperature. In the water-cooled PV solar template system, the wall temperature decreased with the flow of cooling water increase, but the decreasing amount minimized.

H.G Teo et al. [9] reported the efficiency of different configurations of PV module. Without active cooling, the temperature of the module was high and solar cells can only achieve an efficiency of 8-9%. However, when the module was operated under active cooling condition, the temperature dropped significantly leading to an increase in efficiency of solar cells to between 12% and 14% [9].

Kim et al. [6] carried out a study on investigates the effect of operating temperature on the performance and the thermal characteristics of PV modules through a

thermal analysis simulation program. This study showed that the temperature of PV module to attach fins to the backside of PV module was lesser than without fins because heat was emitted at the fins.

W.G Anderson et al. [10] discussed a cooling design that uses a copper/water heat pipe with aluminum fins to cool a Concentrating PV Cells (CPV) by natural convection. Heat pipe can be used to passively remove the heat, accepting a high heat flux at the CPV cell, and rejecting the heat to fins by natural convection, at a much lower heat flux. This work successfully demonstrated the feasibility of a heat pipe cooling solution for CPV [10].

In this investigation, the Sharp Solar Module ND-130T1J has been selected to analysis performance of PV module as function of PV module temperature and solar irradiance by using PVsyst software. PVsyst is designed to be used by architects, engineer, and researchers and supplies the user the PV component size, determines the monthly production and conducts a preliminary economic evaluation of the PV system [11]. PVsyst conduct daily irradiance values averaged over month or hourly values on a period covering a year only [11]. Meteorological database and component management can be conduct by tools of PV syst. A report consisting of parameters and main results provide by components to the user.

II. METHODOLOGY

The basic materials, manufacturing technology and operating conditions will be affected the performance characteristics of a PV module. The conversion efficiency of PV system is important factor to be determined in the power generation technologies. A comparison on the conversion efficiency for different PV technologies under actual operating condition was analyzed in [12, 13] and a mismatch of 2% from the rated value was identified. Besides, the limitation of PV performance operating outdoors for extended periods will degrade more rapidly if initially exposed to sunlight was analyzed in [14, 15] for different PV technologies.

There are several methods for assessing PV performance from a basic model, the use of meteorological data to estimate monthly average generating capacity, more complex models require detailed input, and uses a whole year time series simulation. There are two basic set of inputs to predict the energy system of PV modules which are weather data, PV modules input, and the future of the radiation and temperature output, only from historical data to predict. It was suggested that radiation can significantly predicted differences result in different output, the size of the PV system.

System designers and installers to use simple tools size, scientists and engineers use more sophisticated simulation tools to optimize. Although many software tools, but sometimes it is difficult to assess the adequacy of a specific task, such as pre-feasibility analysis, system

designs, optimization and accuracy requirements of R & D. Furthermore, the input and output of information required will be changed the project progress for system configuration. The PV syst simulation tool used to predict the I-V characteristics curve, P-V characteristics curve and efficiency at maximum power versus different ambient temperature of PV cell.

The manufacturers of PV modules provided general reference values for specified operating condition such as STC (Standard Test Conditions) for which the irradiance level is 1000 W/m², air mass (AM) is 1.5 and the cell temperature is 25°C. A Sharp Solar Module ND-130T1J polycrystalline silicon photovoltaic module with 130W maximum power was used in this simulation. The complete data of the PV module is shown in Table 1.

TABLE 1
THE CHARACTERISTIC OF THE SHARP SOLAR MODULE ND-130T1J

Parameters	Symbol	Value	Unit
Open Circuit Voltage	V_{oc}	22.0	V
Maximum Power Voltage	V_{pm}	17.4	V
Short Circuit Current	I_{sc}	8.09	A
Maximum Power Current	I_{pm}	7.48	A
Maximum Power	P_m	Min. (123.5) Typical (130)	W
Module Efficiency	η	13.0	%
No. of Cells and Connections	-	36 in series	-

Table 1 show that a maximum power 130W, 22.0 V_{oc} , 8.09 I_{sc} with its conventional efficiency 13% under standard test condition (25°C, 1000 W/m²).

III. SIMULATION RESULTS AND DISCUSSIONS

In the I-V and P-V characteristics of a PV module, several parameters in characteristics curve are of particular interest:

- i. Open-circuit voltage (V_{oc}) where maximum voltage through the PV cell and occurs when the current across the PV cell is zero.
- ii. Maximum power voltage (V_{pm}) where voltage when a PV module produces maximum power.
- iii. Short-circuit current (I_{sc}) where maximum current across PV cell and occurs when PV cell with zero output voltage.
- iv. Maximum power current (I_{pm}) where current belonging to maximum power voltage.
- v. Maximum power (P_m) where the product of maximum voltage and maximum current ($V_{pm} \times I_{pm}$)

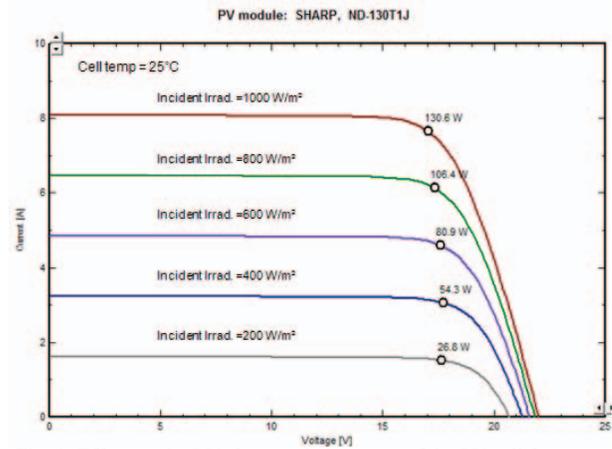


Fig. 1: Effect on the I-V characteristics curve of the PV cell from different incident irradiance.

Figure 1 shows that I-V characteristics curve which will affect its quantity of power generation in constant 25°C cell temperature by different incident irradiance. As solar irradiance constantly changing throughout the day that similar of different I-V characteristics curve. If the incident irradiance is 1000 W/m², the output power is 130.6W while the incident irradiance is 200 W/m², the PV produce 26.8W output power. If the incident irradiance is 800 W/m², 600 W/m² and 400 W/m², the output power is 106.4W, 80.9W and 54.3W respectively. From output power of 200 W/m² incident irradiance increase to 1000 W/m² incident irradiance which is 26.8W to 130.6W, the percentage of efficiency output power is increasing around 79.8%. When the incident irradiance is increasing, both of short circuit current and open circuit voltage also increase and thus the maximum power point also change. If the incident irradiance is higher, the output power is increases as shown in Figure 1.

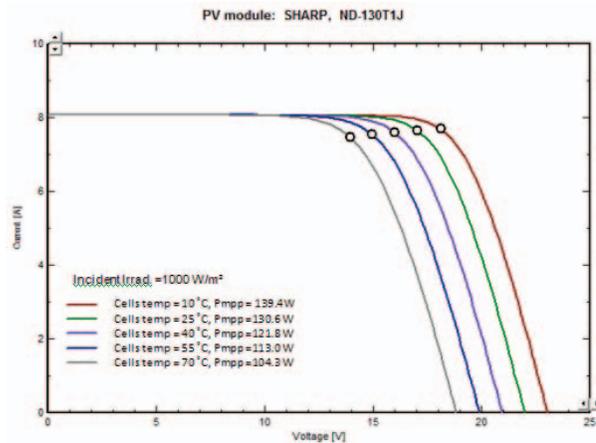


Fig. 2: Effect on the I-V characteristics curve of the PV cell from different ambient temperature.

Another factor which affects quantity of power generation is ambient temperature. In this phenomenon, open circuit voltage is dropping in the result. If the maximum power of PV module is 139.4W with the

ambient temperature is 10°C. The ambient temperature is 25°C, 40°C and 55°C, the maximum power of PV module is 130.6W, 121.8W and 113.0W respectively. If the maximum power of PV module is 104.3W with the ambient temperature is 70°C. By comparing between solar panel with cooling system which the ambient temperature is 10°C, output power is 139.4W and solar panel without cooling system which the ambient temperature is 70°C, and output power is 104.3W, the efficiency of PV cells is increasing to 25.18% by using cooling system. The rate of photon generation increases with increasing temperature so reverse saturation current increases rapidly and that this reduced band gap. The ambient temperature increase causes the voltage move to leftward while decrease in ambient temperature causes the voltage move to rightward as shown in Figure 2.

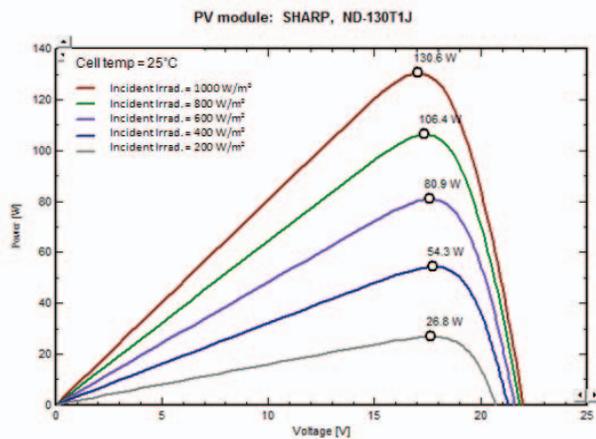


Fig. 3: Effect on the P-V characteristics curve of the PV module from different incident irradiance.

Figure 3 shows effect on the P-V characteristics curve of the PV module in constant 25°C ambient temperature from different incident irradiance which is 1000 W/m², 800 W/m², 600 W/m², 400 W/m² and 200 W/m. As solar irradiance constantly changing throughout the day that similar of different P-V characteristics curve. If the incident irradiance is 1000 W/m², the output power is 130.6W while the incident irradiance is 800 W/m², the PV produce 106.4W output power. If the incident irradiance is 600 W/m², 400 W/m² and 200 W/m², the output power is 80.9W, 54.3W and 26.8W respectively. If the incident irradiance is stronger, then the change of open voltage is smaller, current becomes bigger, the output power increases. If the incident irradiance is weakness, then the change of open voltage is bigger, current becomes smaller, the output power decrease. As the incident irradiance increase causes increase in output current and the part of horizontal of the curve moves upward.

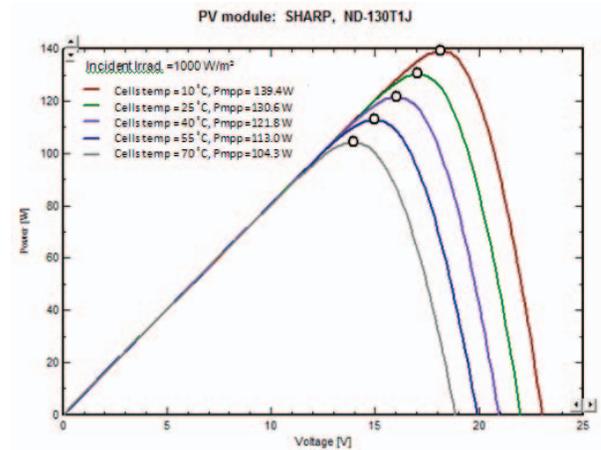


Fig. 4: Effect on the P-V characteristics curve of the PV module with 1000 W/m² incident irradiance from different ambient temperature.

Figure 4 shows effect on the P-V characteristics curve of the PV module with constant 1000 W/m² incident irradiance from different ambient temperature which is 10°C, 25°C, 40°C, 55°C and 70°C. If the ambient temperature is 10°C, the maximum power of PV module is 139.4W. If the ambient temperature is 25°C, 40°C and 55°C, the maximum power of PV module is 130.6W, 121.8W and 113.0W respectively. If the maximum power of PV module is 104.3W with the ambient temperature is 70°C. If the ambient temperature is decrease, the voltage of PV module is increase. On the other hand, if the ambient temperature is increase, the voltage of PV cell is decrease. Thus, the ambient temperature is decrease with the output power is increases while ambient temperature is increase with the output power is decrease. The higher ambient temperature causes the efficiency of PV module lower

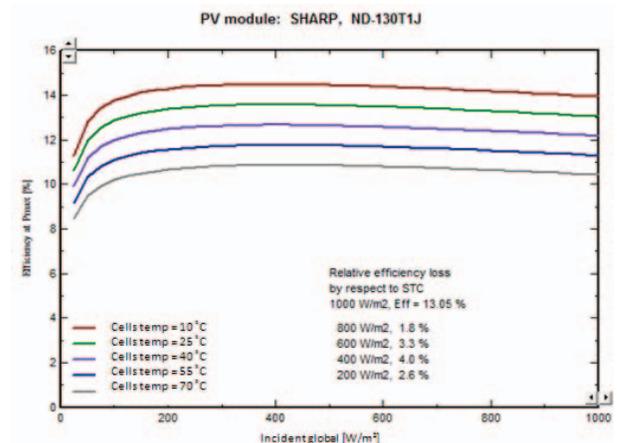


Fig. 5: Efficiency at maximum power versus ambient temperature.

Figure 5 shows an increase in ambient temperature causes the efficiency of PV module decrease and the part of horizontal of the curve moves downward and vice versa. The ambient temperature of PV module is 10°C, the efficiency of PV module is 14% while the ambient temperature of PV module is 70°C with the efficiency of PV module is 10.3%. The ambient temperature of PV

module is 40°C and 55°C with the efficiency of PV module is 12.4%, 11.3% respectively. The ambient temperature of PV module is 25°C; the efficiency of PV module is 13.05% is almost same with standard test condition. As the ambient temperature of PV module decrease, the efficiency of PV module increases and vice versa. The incident irradiance is 1000 W/m², the efficiency of PV module is 13.05%. The efficiency of PV module is 11.25%, 9.75% and 9.05% with the incident irradiance is 800 W/m², 600 W/m² and 400 W/m² respectively. While the incident irradiance is 200 W/m², the efficiency of PV module is 10.45%. The incident irradiance is stronger, the efficiency of PV module increase and vice versa.

IV. CONCLUSION

This paper has presented different ambient temperature effect and different incident irradiance effect to the performance of PV module. In this PVsyst simulation results show that the efficiency of PV module was affected by incident irradiance and ambient temperature. If the incident irradiation and ambient temperature is changing, the current and voltage outputs of the PV array will follow varies. The efficiency of PV module increases as the ambient temperature decreases. The incident irradiance of PV module is 1000 W/m², the output power of PV module is 130.6W while the incident irradiance of PV module is 200 W/m², and the output power of PV module is 26.8W. The higher efficiency of PV cell, the payback period of the system can be shorted and the lifespan of PV module can also be longer.

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