Performance Analysis of PV Solar Water Pump System

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Abstract – In this project, the performance of PV solar water pump will be studied. The objectives of this project are to study the operation of PV solar water pump, to study the performance of PV solar water pump and to develop and construct a simple sensor of flow rate to determine water flow rate monitored by using DataTaker DT80m. The performance of solar water pump is depending on the strength of PV solar panel that converts the electrical energy from sunlight. It is relationship between the strength of sunlight that be absorbed by PV solar panel and the quantity of water that can be flow by the water pump. Other factor that can affect the quantity of water pumped by solar water pump is the pressure of the water. This factor will be studied by using the flow rate that attach to the pipe which connected to the solar water pump. The flow rate will be monitored by using DataTaker DT80m to analyze this factor that can affect the quantity of water that pumped by water pump. The diameter of pipe used in the water pump system is fixed. The analysis is made by varying the pressure of water and the pressure is varied by adjusting the height of pipe from the water pump. From the data, it can be interpreted by plotting the graph so that it can be easily to see the relationship between the parameters. Therefore, the data will be validated. This analysis starts from 7.00am until 7.00pm for everyday and this analysis is running approximately six weeks to complete.

I. INTRODUCTION

Today, the renewable energy is the energy that comes from natural resources and it become more importance to get the electrical energy [1]. It is because the renewable energy is not run out and the renewable energy technologies are clean and will not affect the environment. That's why the renewable is become more popular and many countries are attracted to build the renewable energy technologies even though it is expensive. Besides that, many people have started to design the electrical devices by using renewable energy as electrical energy source such as PV solar water pump. Photovoltaic (PV) is the device that can use light energy or photons from sunlight and turn it to electrical energy [2].

The application of a solar photovoltaic (PV) water pumping system has received increasing attention recently because of the expected cost reduction in PV array. This PV solar panel produces a DC type of output current [3]. More than 2 billion people, mostly in developing countries, live in remote areas without access to grid-connected power [4].

The project is focus on analyze the performance of PV solar water pump. A solar water pump is an electric pump which the source of electricity is generated by photovoltaic panels [5]. This analysis is to study about the strength of water pump if it is powered by PV solar energy. The PV array output is a nonlinear and time-dependent power supply that varies with solar intensity, so the performance characteristics of the PV-powered dc motor are different than when powered by constant voltage[4]. For PV water-pumping application, the selection of a dc motor with appropriate design parameters and pump load is also important [6]-[7]. The operating characteristics of the dc permanent-magnet (PM) motor with thermally protected have suitable matching with PV array characteristics [7]-[8].

In this work, the performance of this solar water pump are analyzed at different solar irradiance and corresponding the pressure of water that pumped by solar water pump. The performance analysis of such types of systems will be useful to find the suitability of it at a region in which the system is supposed to be installed. If average solar intensity of that region is known, then the system parameters could be chosen in such a way that the operating curve should match with the PV array maximum-power points locus[4].

II. OBJECTIVE

The objective of this project is to study, understand and implement the operation of PV solar water pump. The reason to understand the operation of solar water pump is that the performance of the solar water pump can be analyzed. In order to analyse the performance of solar water pump, a flow rate sensor has been developed to measure the amount of water that can be pumped by solar water pump in a day. This flow rate is monitored by using DataTaker DT80m and the data can be displayed at once. Besides that, pyranometer also has been installed near to the solar PV panel to measure the solar irradiance. This pyranometer also has been monitored by using DataTaker 80m. Then, the relationship between the flow rate of the solar water pump and the solar irradiance can be analyzed.

III. METHODOLOGY

The experiment setup consists of 2 PV modules (1 series * 2 parallel), a solar water pump, a flow rate sensor, a pyranometer, a Datataker, a water reservoir tank, etc. In order to do the performance analysis of PV solar water pump system, the first step that must be taken is study about the water pump. It is importance to know about the basic operation of water pump so that the analysis can be performed. Type of solar water pump used is SHURflo Submersible Pump model: 9325. Figure 3.1 shows the type of solar water pump used. The maximum input voltage and input power of this pump are 24V DC and 120W respectively. It means that the solar panel that can produce maximum voltage of 24V can be used as a power supply for this pump. Figure 3.2 shows the technical specifications of the pump.



Figure 3.1: Solar water pump

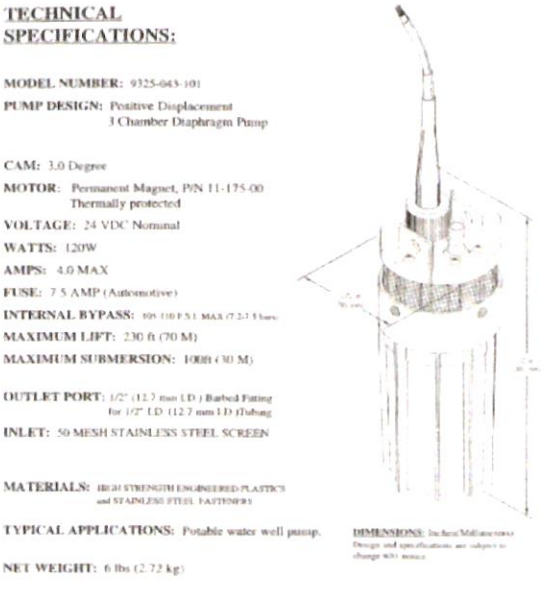


Figure 3.2: Solar water pump specifications

Second step is to decide the flow rate device to be used in the analysis. The flow rate device must be studied first because the maximum flow rate of the flow rate device must be higher than the maximum flow rate of water that can be pumped by the solar water pump. This device will be use to measure the flow rate of water that pumped by the PV solar water pump. The Figure 3.3 shows the flow rate that used for the analysis. Type of this flow rate is Turbine Flow Rate Sensor of FT-110 Series. The range of flow rate that this flow rate device can measure is 0.5-5 L/m the input power of this flow rate is 5–24 VDC. Figure 3.4 show the specifications of this flow rate.



Figure 3.3: Flow rate

Specifications

Wetted Parts	Body: Nylon 12/Turbine: Nylon 12 Composite/Bearings:
Operating Pressure	200 psi
Burst Pressure	2500 psi
Operating Temperature	-4° to 212°F (-20° to 100°C)
Viscosity	32 to 81 SSU (8 - 16 Centistokes)
Filter	< 50 Microns
Input Power	5-24 VDC @ 8 mA
Output	NPN Sinking Open Collector @ 50 mA, Max
Accuracy	± 3% of Rdg. Normal Range
Repeatability	0.5% FS Normal Range
Electrical Connection	Spade Terminals .110/.248 X .031" (2.8/6.3 X .8 mm) or

Figure 3.4:Flow rate specifications

The range of flow rate that this flow rate device can measure is 0.5-5 L/m the input power of this flow rate is 5–24 VDC. Figure 3.4 and Table 3.1 show the specifications of this flow rate.

Table 3.1: Table of flow rate device

Part Numbers		Flow Ranges				Pulses		Frequency
		Normal		Extended				
3/8" NPT	G 3/8 Port	GPM	LPM	GPM	LPM	Per Gallons	Per Liters	Output
173931	173936	1.3 - 1.3	5 - 5	0.7 - 2.6	2.5 - 10	26100	6900	58 - 575 Hz
173932	173937	2.6 - 2.6	1 - 10	0.7 - 2.6	2.5 - 10	12500	3300	55 - 550 Hz
173933	173938	2.6 - 4	1 - 15	0.7 - 4	2.5 - 15	17400	4600	76 - 1150 Hz
173934	173939	2.6 - 4	1 - 15	0.7 - 5.3	2.5 - 20	8300	2200	37 - 550 Hz
173935	173940	5.3 - 7.9	2 - 30	1.3 - 7.9	5 - 30	3600	1000	33 - 500 Hz
173931-C	173936-C	1.3 - 1.3	5 - 5	0.7 - 2.6	2.5 - 10	26100	6900	58 - 575 Hz
173932-C	173937-C	2.6 - 2.6	1 - 10	0.7 - 2.6	2.5 - 10	12500	3300	55 - 550 Hz
173933-C	173938-C	2.6 - 4	1 - 15	0.7 - 4	2.5 - 15	17400	4600	76 - 1150 Hz
173934-C	173939-C	2.6 - 4	1 - 15	0.7 - 5.3	2.5 - 20	8300	2200	37 - 550 Hz
173935-C	173940-C	5.3 - 7.9	2 - 30	1.3 - 7.9	5 - 30	3600	1000	33 - 500 Hz

Besides that, the pyranometer also must be studied in order to measure the solar irradiance. The type of pyranometer used is Pyranometer Sensor SKS 1110.



Figure 3.4: Pyranometer

SKS 1110 SPECIFICATIONS

Dimensions	Weight	Construction	Cable	Sensor	Detector	Filters	Sensitivity -current (1)	Sensitivity -voltage	Working range (2)
30mm 30mm	130g (with 3m cable)	Material Dupont Delrin fully sealed to IP68	2 core screened DEF std 61-12/4.5	Cosine corrected head	Silicon photocell	N/A	5μA/100 W m^{-2}	1mV/ 100 W m^{-2}	0-5000 W m^{-2}
Linearity error	**Absolute calibration error (3)**	**Cosine error (4)**	**Azimuth error (5)**	**Temperature coefficient**	**Long term stability (6)**	**Response time (7) - voltage output**	**Internal resistance - voltage output**	**Temperature range**	**Humidity range**
<0.2%	typ. <3% 5% max.	3%	<1%	±0.2%/°C	±2%	10ms	c.200 ohms	-30 to +75°C	0-100% RH

Figure 3.5: Pyranometer specifications

Figure 3.4 and Figure 3.5 show the pyranometer used and the specifications of the pyranometer respectively. The sensitivity voltage of this pyranometer is 1mV/100Wm^{-2}.

Then, the flow rate device and the pyranometer device will be monitored by DataTaker DT80m. Actually, DataTaker DT80m can measures digital signal and analog signal. Since the flow rate produce digital signal and the pyranometer produce analog signal, so these devices can be monitored by DataTaker DT80m alone. Figure 3.6 shows the DataTaker DT80m that has been used. In order to use this device, a few experiments must be conducted on the flow rate device and the pyranometer device. The objective of these experiments is to synchronize the measurement of flow rate and solar irradiance taken manually with the measurement that displayed by the DataTaker DT80m. After that, a wiring circuit has been constructed.



Figure 3.6: Datataker DT80m

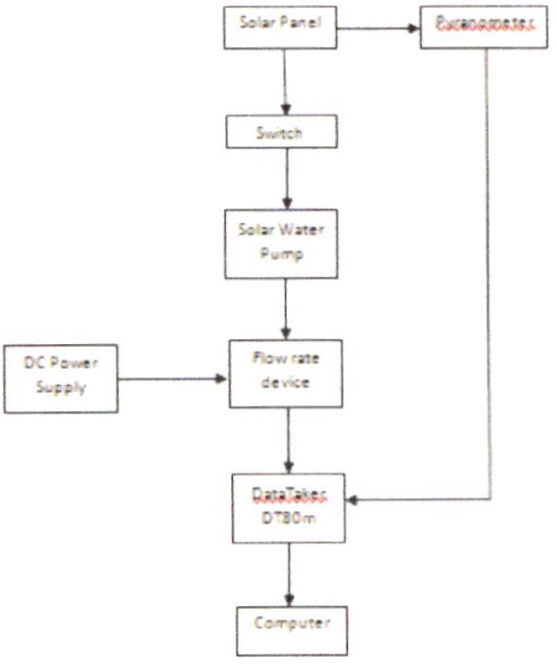


Figure 3.7: Block diagram for wiring circuit

This circuit will show the connections of all the components and the devices. Figure 3.7 shows the block diagram of the wiring circuit and Figure 3.8 shows the schematic diagram of wiring circuit. After all the wiring and the connections are completed, the performance analysis of the solar water pump can be started and the pressure of the water will be adjusted everyday by increase the height of the pipe from the pump. So, the performance of the solar water pump can be analyzed.

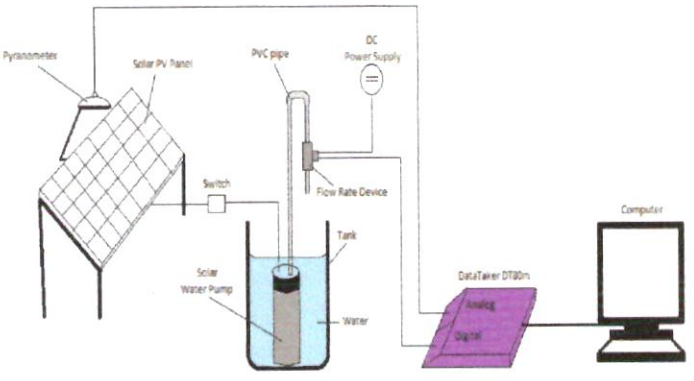


Figure 3.8: Schematic diagram of wiring circuit

Figure 3.9 shows the flow chart of this whole project. After the analysis is done, the conclusions and recommendations can be made. This part is importance because it can be as a guideline for the consumer and other people in the future who want to use a renewable energy as a main power supply so that they can make some improvement to the system become more systematic and profitable.

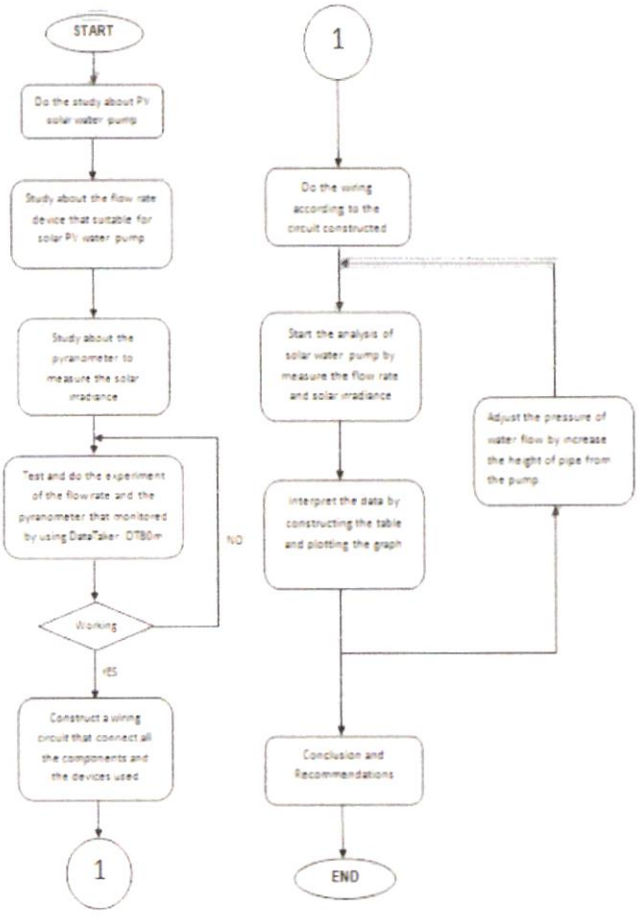


Figure 3.9: Project flow chart

IV. RESULT AND DISCUSSION

Upon implementing the Performance Analysis of Solar PV Water Pump, several experiments had been done. The performance analysis of water pump has been done by varying the height of pipe from the water pump. Data logging have done for one day for each experiment. The data has been taken one minute interval and starting from 8.45am until 7.00pm. The data has been obtained at different solar intensity. The flow rate and the solar irradiance at 1m, 2m, 4m, 6m and 8m height of the pipe from water pump are shown in figure 4.1, figure 4.2, figure 4.3, figure 4.4 and figure 4.5. The curves show the relationship between the flow rate of the water that pumped by the water pump and the solar irradiance.

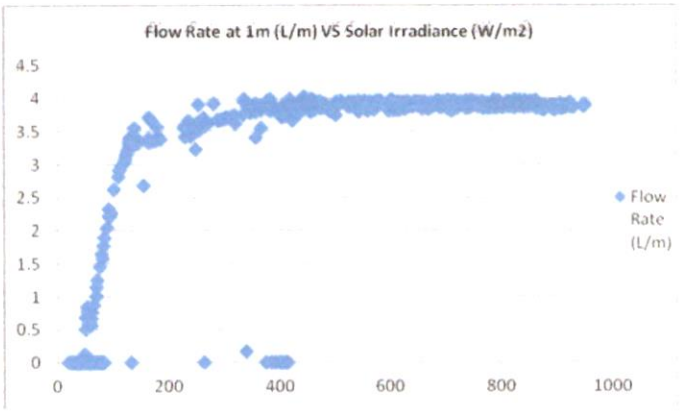


Figure. 4.1: The result for Flow rate (L/m) against solar irradiance (W/m^2) at 1m height of the pipe

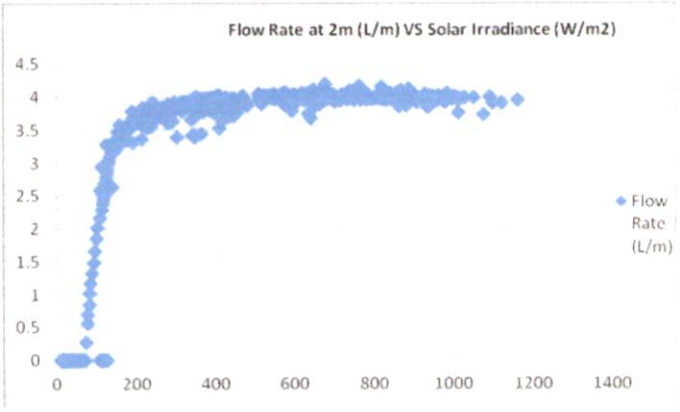


Figure 4.2: The result for Flow rate (L/m) against solar irradiance (W/m^2) at 2m height of the pipe

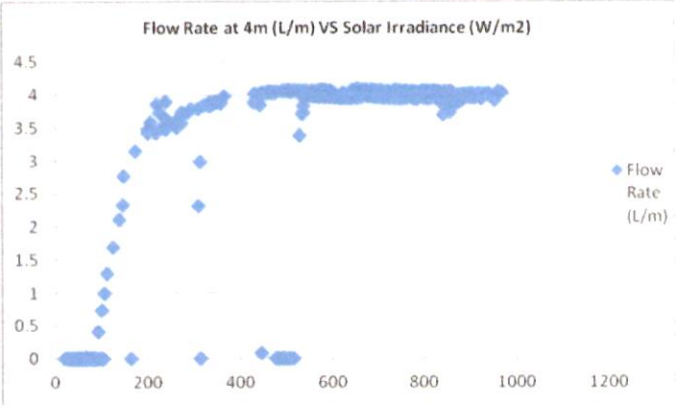


Figure 4.3: The result for Flow rate (L/m) against solar irradiance (W/m^2) at 4m height of the pipe

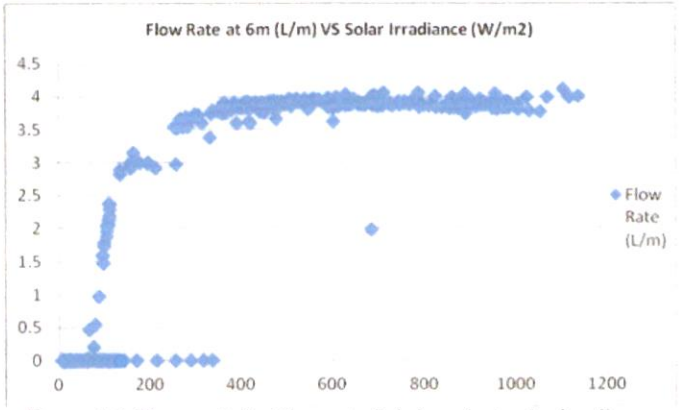


Figure 4.4: The result for Flow rate (L/m) against solar irradiance (W/m^2) at 6m height of the pipe

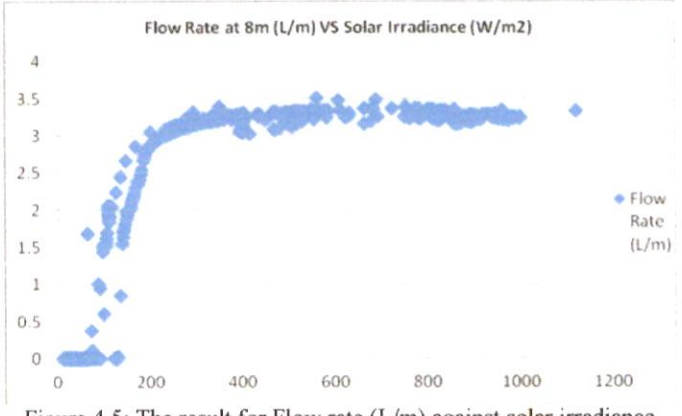


Figure 4.5: The result for Flow rate (L/m) against solar irradiance (W/m^2) at 8m height of the pipe

So far, five experiments have been conducted to investigate the variation of water flow rate against solar irradiance. For the purpose of this study, the test cases were divided into five sets as shown in Figure 4.1 to 4.5 above. The results show that the water flow rate is increase linearly as solar irradiance increase. When solar irradiance reaches above $400W/m^2$, the water flow rate starts to become constant with range 3.8L/m to 4.1L/m. It shows that the strength of solar water pump is depend on the solar intensity that received by PV panels and the water flow rate will keep increasing until the output voltage from the panel reaches its maximum output voltage. The maximum output voltage of the panels is 18.81V. So far, even thought the height of pipe from water pump has been increased to six meter, the water flow rate values do not much difference with one meter height of the pipe. It also shows that the solar water pump can maintain the water flow rate even thought it must pump the water up to six meter of height. But when the height of the pipe is increased to eight meter, the values of the water flow rate starts to reduce at range 3.2L/m to 3.4L/m. It shows that the strength of solar water pump become weaker when the height of the pipe is more than six meter. Besides that, from the graphs above also there have some points where the water flow rates are almost zero even the solar irradiance values are above $200W/m^2$. It is because the pyranometer that measure the solar irradiance is not shaded from sunlight but PV panels are still shaded from the sunlight. The shaded is come from a building which is Kolej Teratai where it is near the research site.

V. CONCLUSION

The performance analysis of PV solar water pump system has been analyzed at different solar irradiance and height of the pipe from the water pump. It has been observed that the system operates most of the daytime because of the solar water pump will starts operates immediately as the PV panels receive enough solar irradiance. From the results obtained, the water flow rate is increase linearly as the solar irradiance increase. Besides that, the value of water flow rate also does not much difference as the height of the pipe from the solar water pump is increased up to six meter. But when the height of the pipe is increased to eight meter, the values of the water flow rate starts to reduce. It shows that the strength of solar water pump become weaker when the height of the pipe is more than six meter. So, it can be conclude that the strength of the solar water pump to pump the water is depend on the solar irradiance that received by the PV panels but it can maintain its strength even it must pump the water up to six meter of height.

The performance analysis of PV solar water pump system will be useful to select the suitable motor and load for water-pumping applications in remote areas. If the average solar irradiance of a region in which the system is to be installed is known, then the parameters of the system components could be chosen by referring to the performance analysis. Thus, a higher system efficiency and, in turn, higher flow could be obtained.

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