PERFORMANCE ANALYSIS OF
THE PHOTOVOLTAIC WATER PUMPING SYSTEM
AT AN EDUCATIONAL INSTITUTE

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Abstract

Photovoltaic (PV) water pumping system is an appropriate way to supply water in locations where access to electric power is an expensive. Solar energy is a logical solution because maximum water demand occurs during periods of maximum sunshine. Due to the fact that the viability of a solar pump depends on a low initial cost and long working period without maintenance. Energy efficiency and simplicity are of paramount importance in the design. The PV water pumping system in this work has been installed at Rajamangala Institute of Technology (main campus), Klong 6, Thanyaburi district, Pathumthani province of Thailand. It is mounted on a small farm to supply the water for pouring water on garden plants. The PV pumping system with 490 W_p is able to produce the water averagely of 1,250 liters/day based on the climate data at the design location. The programme computer using visual basic was developed for design PV array sizing and system components.

Keywords : PV System –1; Water Pumping – 2

1. INTRODUCTION

There are many reasons that makes PV pumping for agricultural exploitations one of the applications of the solar energy with more market potential, not only in remote or isolated areas where it is the only reasonable option. Among these reasons, they can be addressed as follows:[1] (a) the coincidence between crops and water demand and solar radiation availability, making gratuitous energy contribution to be usually bigger when it is more necessary and then, making to the users more conscious of the suitability of the solar energy use, (b) the goodness of decentralized energy sourced to feed disperse facilities as well or reservoirs, (c) the lower costs regarding other PV stand alone systems because the possibility to store mechanical energy instead of electricity an finally, (d) due to the fact that the socio-economic benefits of the solar pumping are usually more immediate and evident that in the case of other solar applications. Nevertheless, there are some small plants (farms) that to be carried out within the area of the Rajamangala Institute of Technology (main campus), Pathumthani province of Thailand. One of the purposes of these small plants is for

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maintenance on the garden plants that to be grown in the flowerpot. Normally, in the morning, many workers who have responsible for maintenance the flowers will dip up the water from a pond for pouring water on garden plants. The process must be repeated in the evening on the same day. In this case, many workers and loss of time are certainly necessary. Due to the fact that the manpower for working in the small plant (farm) have been strongly limited and are also very rare. To reduce some workers who work in the small plant, a PV water pumping system is suitable for installing as stand alone power supply system. The PV power system that concerning with the period of time for operating must be controlled by electronic devices. Accordingly, a 490 W_p of PV water pumping system was designed by programme computer using visual basic. This is based on climatic data at the design location, daily load demand, I–V characteristic of a solar module and so on. In addition, the PV pumping system was tested and was analyzed after installing.

2. SYSTEM COMPONENTS

The system consists of a few simple units only, which are connected to form a complete system.

2.1 Photovoltaic Module

There are 7 modules that have been mounted. They are connected in parallel for supplying the electric power to motor. The PV module # BP 270 U was selected. Its characteristics are as follows:

Rated power	70 watts@ 25°C
Voltage @ max. power	17.0 volts
Current @ max. power	4.16 amps
Short circuit current	4.48 amps
Open circuit voltage	21.4 volts
Warranted minimum	65 watts
Maximum system voltage	600 volts
Temperature coefficient of I_{sc}	(0.065−0.015) %/°C
Temperature coefficient of V_{oc}	−(80−10) mV/°C
Temperature coefficient of power	−(0.5−0.05) %/°C
NOCT	47−2°C
Dimension	50 cm × 120 cm
Weight	50 Kg

(1) These data present the performance of typical BP 270 U module as measured at their output terminals. The data are based on measurements made in accordance with ASTM E1036−85 corrected to SRC (Standard Reporting Conditions, also known as STC or standard test conditions), which are: (a) illumination of 1 kW/m² at spectral distribution of AM 1.5 (ASTM E892−87 global spectral irradiance) and (b) cell temperature of 25°C.

(2) The cells in an illuminated module operate hotter than ambient temperature. NOCT is an indicator of this temperature differential, and is the cell temperature under Standard Operating Conditions, ambient temperature of 20°C, solar radiation of 0.8 kW/m², and wind speed of 1m/s.

The design of PV module sizing is mainly based on the climatic data on inclined surface at latitude angle of Pathumthani province of Thailand and daily load demand. Accordingly, the PV modules have been mounted on the top of a mast that having a slope of angle is about 14°, this is the latitude angle of Pathumthani province [2], facing to the south of a compass. The DC output from the array is transmitted to the inverter through a main switch in the inverter.

2.2 Controller

In this work, the regulator from BP solar # GCR 2000 has been mounted to control the state of charge and discharge of the battery. Maximum rated current for this type is about 20 A. this charge control is specifically developed for charging battery powered by photovoltaic modules. It includes an LCD display that provides continuous battery storage and battery bank conditioning data. PV pumping system requires a charge controller (battery regulator) to control the energy flow and the charge condition of the battery.

2.3 Inverter

the inverter of model # G-12-150 has been mounted for transforming the voltage level from DC to AC. The AC output voltage and frequency vary continuously as a function of the irradiation. Its characteristics are as follows:

Output power 25 min	1500 watts
Output power 10 min	1700 watts
Output power continuous	1200 watts
AC output	220 volts
Regulation	-5%
Output waveform	modified waveform
Phase	single phase
DC input voltage	10-15 volts
Low battery alarm	10.7 volts
Low battery shut down	10 volts
Frequency	50 Hz
Efficiency	85-90%

2.4 Battery

In this work, the battery with maintenance free type #DJM12120 has been mounted. The rated voltage and ampere-hour are 12 volts and 120 ampere-hour respectively.

2.5 Water storage tank

There are 2 storage tanks for storing the water. Each of them has a rated capacity of 5000 m^3.

3. LIFE CYCLE COST ANALYSIS

The life cycle cost analysis (LCC) is the appropriate method to find out the system cost. The initial costs and all future costs for the entries operational life of a system are considered. To make a meaningful comparison, all future costs and benefits have to be discounted to their equivalent value in today's economy. All future costs and benefits are discounted to the present worth or present day values. A LCC analysis is based on the key assumptions (year 2003). The costs of installation and operation and maintenance are estimated by multiplying the capital cost of PV arrays with 0.2 (20%) and 0.02 (2%) respectively. The results of an analysis was found that the value of level energy cost was 60.8 baht/kW (1 US$ $\approx$ 48 baht) approximately. This is based on 25 years of the period of life time for analysis and the value of the inflation rate is 5%.
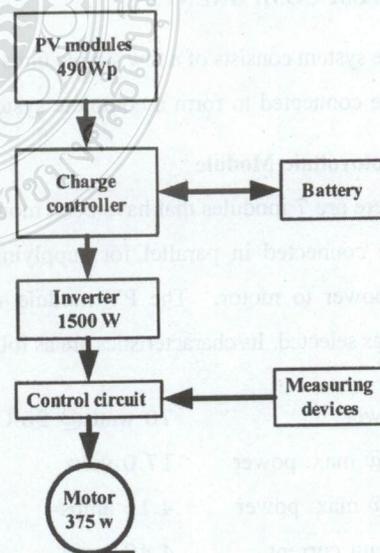

Figure 1: Block diagram of PV pumping system on AC motor side.

4. EXPERIMENTAL TESTING

In this work, some parameters were measured during 08.00 hour to 16.00 hour. Each period of time is every 2 hours. The data can be shown as follows:

Table I: Data from measurement at Rajamangala Institute of Technology, Pathumthani province, Thailand only on specific day

| Date	Time (hour)	Insolation (W/m²)	Current (A)	Voltage (V)	Power (W)
10 March 2004	08.00	406.83	6.50	12.11	78.70
	10.00	625.69	6.80	12.45	84.70
	12.00	693.33	7.0	12.55	87.9
	14.00	360.32	6.0	12.45	74.7
	16.00	135.50	3.5	12.16	42.60
Average value		444.35	5.96	12.34	73.72
The water can be pumped = 1500 liters/day					

The value of the current, voltage and power shown in the table I are generated output of the solar cell. The data was daily recorded throughout 2 month between January and March 2004.
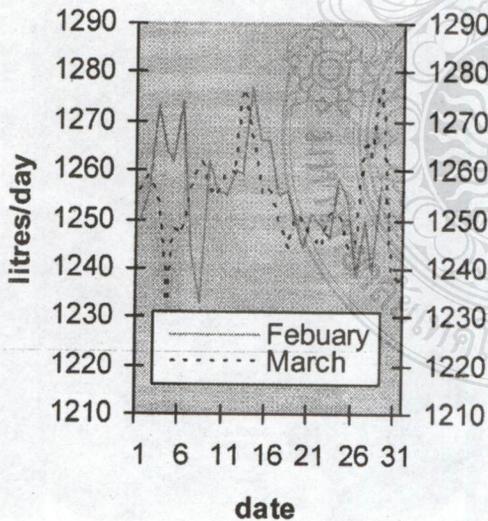
Figure 2: rate of flow of the water from storage tanks for pouring water on garden plants during the month of February and March at design location (Rajamangala Institute of Technology – Main campus)
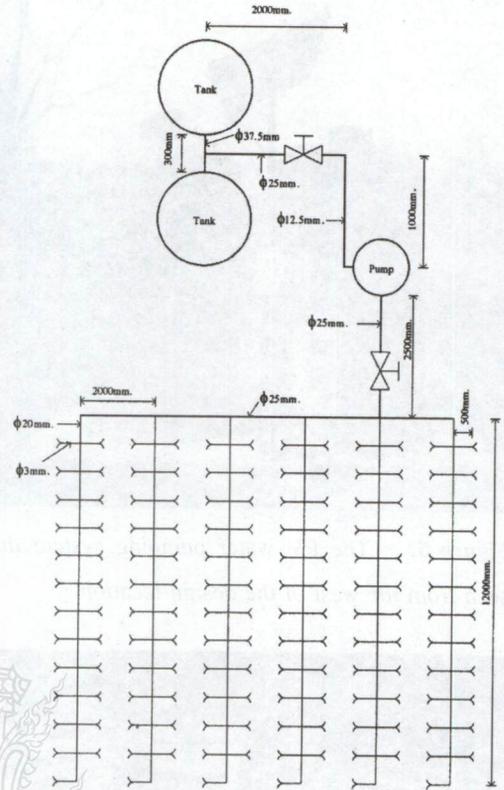
Figure 3: Layout of the rubber piping system from the water storage tank for supplying the water to each garden plant that to be grown in the flowerpot at Rajamangala Institute of Technology
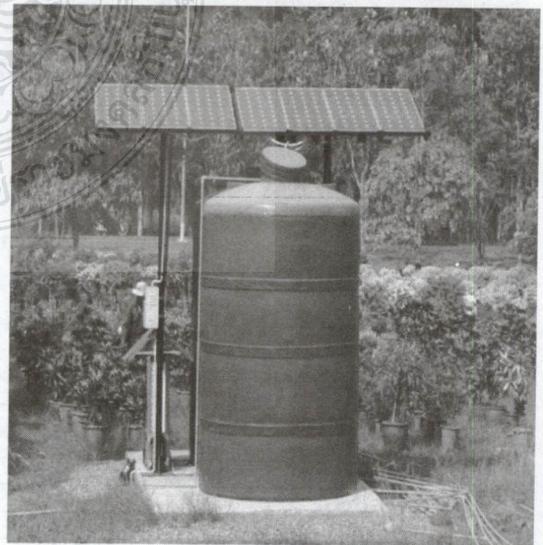
Figure 4: The PV water pumping system that seen from the south of the design location

Figure 5: *The PV water pumping system that seen from the west of the design location*

Figure 6: *The garden plants in the flowerpots are supplied by the water from storage tank.*

Table II: an average value of performance system that to be measured at AC motor side.

Month	February - March	
Time (hour)	8.00-8.30	16.00-16.30
Water supplied (litres)	634	627
Water pressure (bar)	1.25	1.20
Motor voltage (Vac)	227.50	227
Motor current (Aac)	2.80	2.80
Power factor	0.80	0.80
Power (watts)	509.6	508.5
Battery voltage (Vdc)	13.2	13.5
Discharge current (Adc)	38.6	37.7

5. CONCLUSIONS

The PV water pumping system at rated 490 W_p has been installed at Rajamangala Institute of Technology, Klong 6, Pathumthani province of Thailand. It was mounted to daily supply the water for pouring water on garden plants. A number of the flowerpots on a small plant (farm) is 250 approximately. The data from measurement and testing are able to be addressed as follows: (a) the water of 1,500 litres can be daily pumped. (b) the request of water supply for pouring water on garden plants is about 1,250 litres/day. (c) the power factor of AC motor and current are quite constant. Although, in this work an inverter with modified sine wave type was installed, the inverter with pure sine wave type should be chosen to improve the power factor and reduce the motor current completely.
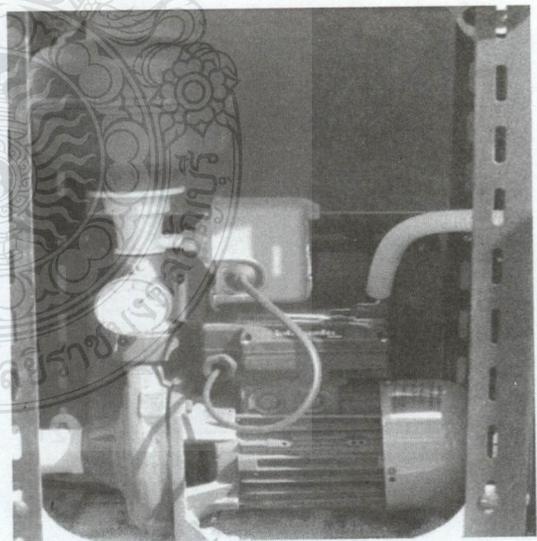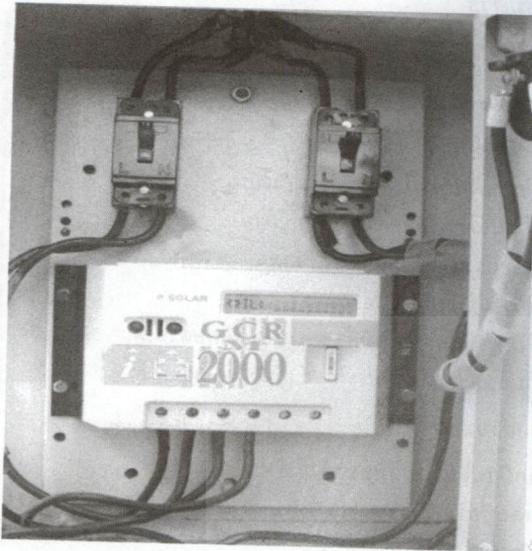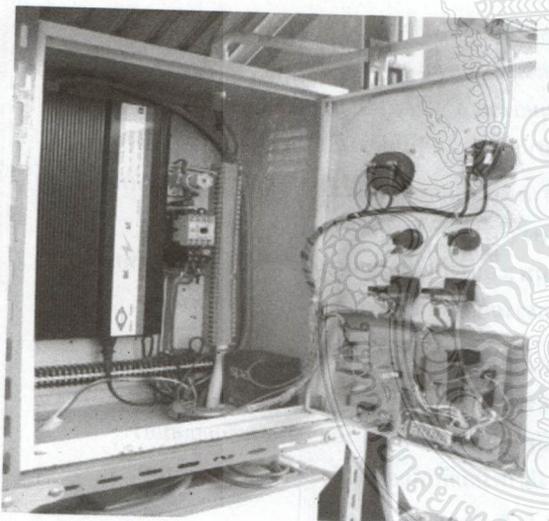

Figure 7: *AC motor for pumping the water from the storage tank for pouring water on garden plants.*

Figure 8: A regulator to control the state of charge
of the battery

Figure 9: An inverter to convert DC–AC with
controlling circuit

6. REFERENCES

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Assistant Professor Somchai Hiranvarodom received the Ph.D. degree in electrical engineering from University of Northumbria at Newcastle, UK. He has been a lecturer at the Department of Electrical Engineering, Faculty of Engineering, Rajamangala Institute of Technology (Main campus, Pathumthani province). His main research interests in Photovoltaics (PV) power system and electrical power system.