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Research Article

Performance Analysis of 900W$_p$ Solar Photovoltaic Water Fountain Installed at Energy Park, UTD RGPV, Bhopal

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Abstract

The performance analysis of a solar photovoltaic (PV) array based water fountain system installed at energy park of UTD RGPV campus (state university) M.P., India has been studied. A 1hp DC motor with 900W (12 panels of each 75W$_p$) have been used for discharge 10m water head. The maximum discharge logged 146litre/minute between 10:00 AM to 2:00 PM at PV power output between 110 to 120W/m² and the system is operating approximately 8 hours in the of September of the winter season. The full day discharge has found 70,000 liters and it is more than the average discharge given by the manufacturer at 10m depth. It is exposed that solar PV based water pumping system is a suitable and feasible option for off-grid water fountain like the area of UTD RGPV, Bhopal, where clear sky days are more than 250 in a year.

Keywords: *Solar PV, total head, off-grid, average discharge*

Nomenclature

Ps total solar power at panel
I_r solar irradiation
A_p area of PV module (1.2m×0.55m)
n number of PV module
P_{PV} power generated by photovoltaic panel
V_{OC} voltage of open circuit
I_{SC} short circuit current
ρ water density in kg/m3
g specific gravity in m/s2
Q water discharge m3/s
H total pumping head in m
η_{PV} Array efficiency
η_h Subsystem efficiency
η_O Overall efficiency

1. Introduction

The Indian electrical power generating capacity including both of central and state energy sectors is 210951.72MW in the year of 2012. The Figure 1. shows the rational generation of electricity according to energy resources as 8.96% gas, 57.3% coal, 0.57% DSL, 18.65% hydro, 2.27% nuclear, and 12.26% renewable sources. And the energy consumption by industry 23%, agriculture pumping 18%, residential appliances 18%, residential lighting 13% and services 12% and a small amount is consumed by transportation like Railway.(McNeil & Sathaye, 2009)

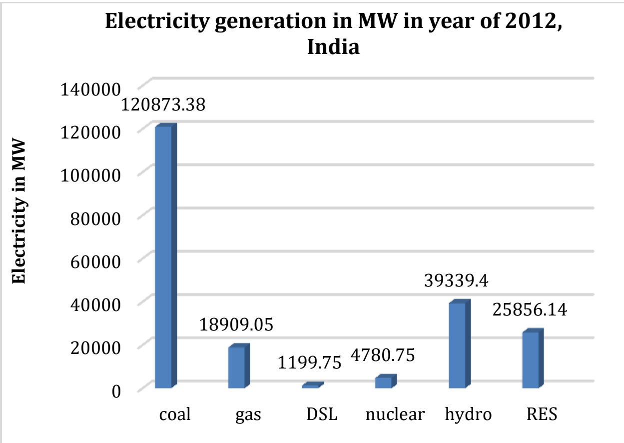

Figure 1 Installed electricity generation capacity in the year of 2012 in India (2012)

The solar photovoltaic water fountain systems (SPWFS) offer the appropriate solution to supply water for decorative and beautifying purpose in any region. Presently, the use of solar photovoltaic water fountain systems represents a promising option for using solar power productively and for creating income.

Solar photovoltaic water fountain systems are noiseless, fuel less, require tiny maintenance and pump most water during the sunniest, hottest days of summer. Other advantages of a PV system are free energy, more reliable power, flexibility, and quick fast Installation.

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2. Solar PV Water Fountain System (SPWFS)

Solar photovoltaic water fountain system is modular, flexible and is of two basic type i.e. shallow well type and deep good type. The fountain systems are extremely rugged, maintenance free and do not need any other external source of power. DC power is generated by a panel at the site itself and fed to the solar pump. They are ideally suitable for those areas. Also, Solar PV pumps require only one-time initial investment with no recurring cost and have a long life.
The system components of SPV water fountain system are:

1. PV array
2. Motor pump set
3. Connecting cables and switches
4. Support structure and tracking system
5. Pipes and nozzles, etc.

2.1 Working of SPWFS

A basic model of the solar PV powered water fountain features a water pump with DC motor connected to a solar PV panel. As there is no battery in the arrangement, the setup will not work during the night. It also may not work during cloudy and rainy season conditions. If the SPWF application is intended to be used only during the daytime, then this option is feasible. If it is proposed to be used in areas with overcast conditions, then the setup must include a battery bank which stores solar energy when the sun is available, and uses it during clouded rainy weather and also during the night.(Solarhome, 2010)

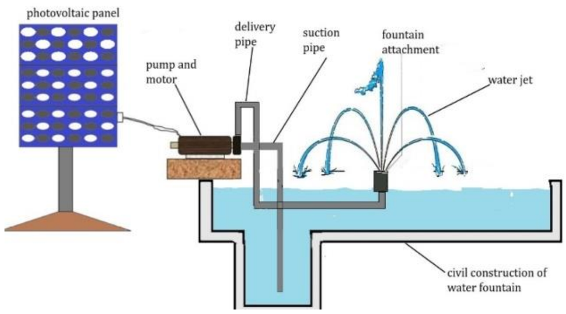


Figure 2 Schematic diagram of solar photovoltaic water fountain

2.2 SPV Array

The solar cell is the primary device for the solar photovoltaic system since it converts solar radiation into electricity. Solar photovoltaic cells are made of fine sheets of silicon wafers, cut to the desire shape. The technology is mainly based on monocrystalline silicon and polycrystalline. A number of such Solar PV cells are coupled in series and (or) parallel connection to design an SPV module of required power. These modules can be further coupled to from Solar PV array, to get desired power output to run the electrical appliances such as a water fountain.

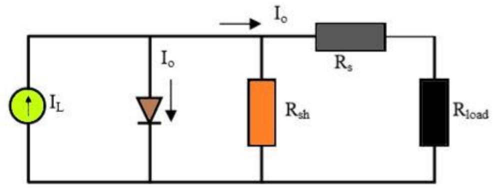


Figure 3 Equivalent circuit of solar cell

The Solar PV array of 900 W_p capacity supply electrical power to the DC pump in the daytime. SPV Array consists of 01 Nos SPV Panels consist of 12 nos. SPV modules are connected in series

2.3 Solar Pump Set

various types of Solar Pump are categories following(Bolaji & Adu, 2007)

(i) Submerged multistage centrifugal motor-pump sets:

They are probably the most common type of solar pump for village water supply. advantages of this type are that it is easy to install and the motor-pump set is submerged away from potential damage. The most commonly employed system consists of an A.C. pump and inverter with PV array of less than 1500W, but D.C. motors are also used.

(ii) Reciprocating positive displacement pumps:

They are very suitable for high-head, low-flow applications, they are often more efficient than centrifugal pumps.

(iii) Floating motor-pump sets:

This type motor pump have a versatility that makes then ideal for irrigation water pumping from canals and open wells. The motor pump set is portable and there is a negligible chance of pump running dry. The solar array support often incorporates a "wheel bar row' type trolley to enable easy transportation.

A high-efficiency DC Monobloc motor pump set of 1 hp is used with solar PV power Pack. Pump and PV module characteristics are designed to match each other for better performance and to utilize maximum power of PV Array. Direct drive DC motor eliminates inverter. The pump is designed to start at low intensity of the sun.

2.4 connecting cable and switches

Copper's electrical properties still make it the best material for conductors and electrical connections. There are, however, also good reasons for using aluminum. The need to connect these two materials together is, therefore, becoming more frequent.

Two protected pole type MCB is used for circuit break switches.

2.5 pipes and nozzle

Cast iron pipes are used for water supply and delivery in solar water fountain.

There are many types and variety of nozzle available in the market but in SPWFS Mild-steel material built conical type nozzle used.it is shown in figure no.4

Fig. 4 Conical water fountain nozzle

3. Specification of solar water fountain System description installed at Energy Park:

REIL's 900 W_p SPV water Pumping System consists of the following:
1. SPV Modules 75 W_p- 12 Nos
2. DC surface Centrifugal 1hp pumps set- 01 Nos
3. Mounting Structure for 12 nos. of Modules with three axis manual tracking.
4. MCB for switching ON/OFF the pump. Solar PV water fountain installed at ENERGY PARK of UTD RGPV Bhopal shown figure no.

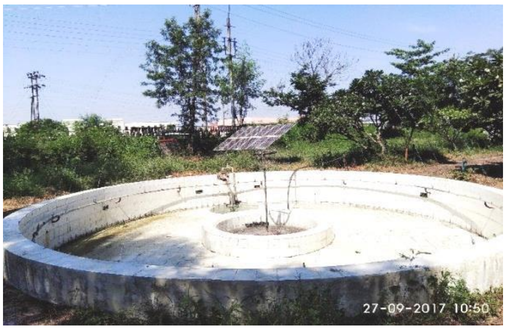


Figure 5 Solar water fountain installed at UTD RGPV

Technical specification of a typical 1 hp SPV fountain:

Solar photovoltaic panels	900 W_p comprising of 75 W_p modules (120cm×55cm)
Number of nozzle	17
Motor pump set type	1 hp centrifugal DC Monoblock
Operating voltage	36V DC (nominal)
Maximum suction head	2.0 meters
Maximum dynamic head	10.0 meters
Bore well size	150 mm diameter
Required shadow free area	100 m²
Module mounting structure	hot dipped galvanized Mild Steel
Average discharge of pump	SPV pump set will have the capacity to give a discharge of 70,000 Liters on clear sunny day (approx.).

4. Calculation and result

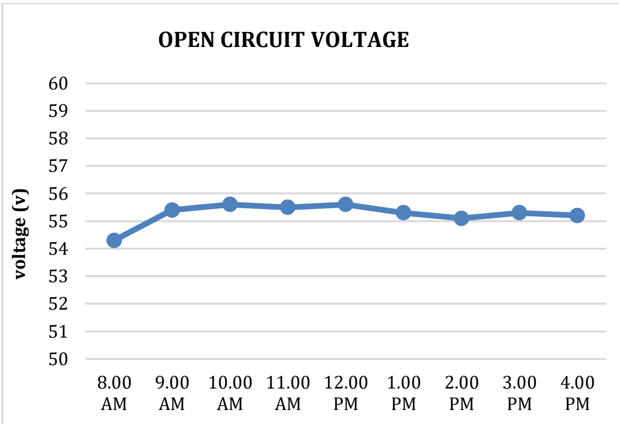
4.1 Solar PV Power calculation

Total pawer generated by solar photovoltaic panel can be calculated by open circuit voltage and short circuit current on panel terminal. Following formulae used for calculated by following formulae

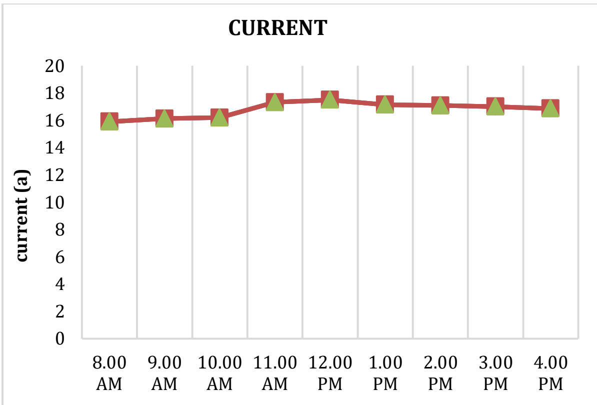
$$P_{PV} = V_{OC} \times I_{SC}$$

Table 1 Voltage, current and power of PV panel

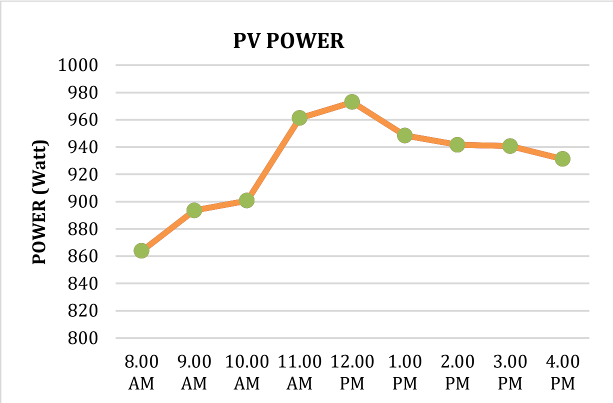
Date – 22/05/2017				
TIME	VOLTAGE (V)		CURRENT (A)	PV POWER (P)
	V_{sc}	V_{oc}		
08:00 AM	16.09	54.3	15.91	863.913
09:00 AM	16.16	55.4	16.13	893.602
10:00 AM	16.2	55.6	16.2	900.72
11:00 AM	16.9	55.5	17.32	961.26
12:00 PM	17.3	55.6	17.5	973
01:00 PM	17.01	55.3	17.15	948.395
02:00 PM	16.65	55.1	17.09	941.659
03:00 PM	16.54	55.3	17.01	940.653
04:00 PM	16.43	55.2	16.87	931.224



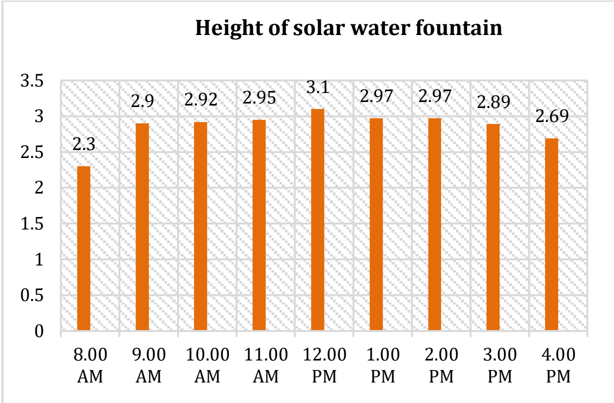
Graph 1 Open circuit voltage of solar PV panel



Graph 2 Short circuit current of solar PV panel with load



Graph 3 Power produced by solar PV module



Graph 5 Time Vs height of solar fountain

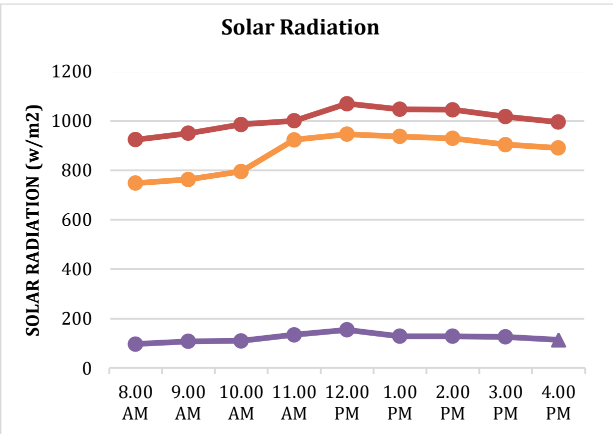
4.2 Solar incident power calculation

Solar incident power can be calculated by using the following expression

$P_S = I_r \times A_P \times n$

Table 2 Height of fountain and various solar radiation

Date – 22/05/2017					
Time	Height of fountain (m)	Solar radiation (w/m²)			Ps (watt)
		Direct	Diffused	Global	
08:00 AM	2.30	924	97	748	7318.08
09:00 AM	2.90	950	108	763	7524
10:00 AM	2.92	985	110	795	7801.2
11:00 AM	2.95	1000	135	923	7920
12:00 PM	3.10	1069	155	946	8466.48
01:00 PM	2.97	1047	129	937	8292.24
02:00 PM	2.97	1045	129	929	8276.4
03:00 PM	2.89	1017	126	904	8054.64
04:00 PM	2.69	995	114	890	7880.4



Graph 4 Daily solar radiation on 22 September at UTD RGPV Bhopal city

4.3 Height of solar fountain

The height of solar fountain is the maximum height of water jet given by one single nozzle. The height of fountain at different time of any day are given in graph 5.

4.4 Efficiencies of solar fountain

4.4.1 Hydraulic efficiency

$$\eta_h = \frac{hydraulic\ power}{PV\ power} \times 100$$

$$\eta_h = \frac{\rho g h Q}{V_{oc} \times I_{sc}} \times 100$$

$$\eta_h = \frac{1000 \times 9.81 \times 10 \times 0.000810}{55.26 \times 16.80} \times 100$$

$$\eta_h = 8.56\ \%$$

4.4.2 PV panel efficiency

$$\eta_{PV} = \frac{PV\ power}{solar\ direct\ radiation} \times 100$$

$$\eta_{PV} = \frac{V_{oc} \times I_{sc}}{I_r} \times 100$$

$$\eta_{PV} = \frac{55.26 \times 16.80}{1003.56} \times 100$$

$$\eta_{PV} = 11.05\ \%$$

4.4.3 Overall efficiency

$$\eta_O = \eta_h \times \eta_{PV}$$

$$\eta_O = 9.46$$

Conclusion

All the variations of radiation, height of water fountain, power and efficiencies with respect to daily times were shown in this research paper. The conclusions of this study are found as follows.

1) Analyze the performance and working of solar photovoltaic operated water fountain at UTD RGPV
2) This system is designed for 10 m head and gives better performance. But the performed system is installed for 6 m water head. It stated that the discharge is depending on the water head.
3) Analyze the VI characteristics curve of the photovoltaic panel and it is shown that at 11:00 AM to 01:00 PM voltage and current of PV array are increases and then after decrease after some time.

4) Graph 5. Clearly given that the maximum height of solar water fountain is maximum at 12:00 PM about 3.1 meters.
5) In this paper, we investigate the comparison of various solar radiation (direct, diffused and global) at RGPV campus.
6) PV panel efficiency of PV panel is 8.56 % and Overall efficiency of solar photovoltaic water fountain is 9.46 %.
7) It is a better alternative because the demand is in the face of solar radiation availability.
8) Save the energy and beautifying the UTD RGPV campus location.

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