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PERFORMANCE EVALUATION OF SOLAR SUBMERSIBLE PUMP

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ABSTRACT

A SP-4-8 Gundfos eight stage 50 mm submersible pump was erected and its performance evaluated at 30 m head in Coimbatore district. The module (Model BHPV-1230A) had an output of 30 W±10 per cent at solar intensity of $100 mWcm^{-2}$. Data on solar intensity, PC module output and pump output were observed for a period of one year. The results revealed that the discharge was directly proportional to solar intensity. The efficiency of PV system in converting solar energy into direct electricity varied from 3.72 to 5.15 per cent up to 50 $mWcm^{-2}$ solar radiation intensity, whereas it was 5.2 to 7.04 per cent beyond 50 $mWcm^{-2}$. The pump efficiency varied from 42 to 54 per cent, but maintained around 43 per cent. The average pump discharge was 1700/h during the two monsoon periods and $2200/h^{-1}$ in summer and winter. The predicted water flow based on sunshine hours varied from 19.000 - 21,700/day in winter and 17,300 - 20.0001 day^{-1} day in summer. The same during south west and north east monsoon periods were 7600 - 12,0001 and 11.500 - 13.500 / day^{-1} respectively.

KEY WORDS : Solar pump, P-V panel, Pump efficiency

Photo voltaic conversion of solar energy into electricity has reached a new high in the recent past and is receiving maximum attention of the scientists and technologists throughout the world. There is a progressive improvement of performance in the newer PV systems and also reduction in cost. In India, the cost of the PV module has come down to 50 per cent. Thus there is a good scope of availability of PV modules at reasonable price in the near future.

India has solar energy potential of 5 to 7 $kWhm^{-2}$ (Satyanarayana, 1989) and is best suited for this technology. The vast land area with differing terrain has made the transportation of fossil fuels to remote areas a difficult preposition. Thus the PV technology is being considered a viable option for farm activities. This possibility of its competitiveness with other fuels even in inland areas is very bright. This study was undertaken to evaluate a photo voltaic submersible pump to investigate its suitability for feasible application.

MATERIALS AND METHODS

The solar submersible pump (Fig. 1) consisted of a PV array, a DC-AC inverter, a motor and pump. Each module consisted of 36 monorcystal silicon solar cells. At 100 $mWcm^{-2}$ solar intensity, each module output was 30 10 W. The sub array contained 8 modules in series and 5 sub arrays were connected in parellel to get 120 V with 10 A. The total cell area of the panel was 12 m^2. The electronic inverter converted the DC power into three phase variable frequency AC power. The power was transmitted to the mottor to drive a SP-4-8 Gundfos 8 stage 50 mm size submersible pump.

The SP-4-8 Gundfos solar submersible pump was erected in a 250 mm dia well of 90 m deep. It was tested at 30 m head to assess its performance for one year. Data on solar intensity, PV module output and pump output (water discharge) were recorded chronologically.

The solar intensity was measured using a pyranometer. The PV panel output was recorded with DC voltmeter and ammeter. The pump discharge was measured using a water flow meter of 4 m^3h^{-1} capacity. The above parameters were measured every half an hour.

The data observed was analysed as that of a factorial experiment with 48 treatments and five replications. Each treatment represented observations recorded in a week and replications as that of each day in that week. The maximum and minimum solar intensities and pump discharge were the variables evaluated as influenced by the weeks of different seasons.

Table 1. Analysis of variance on

a. Maximum solar intensity

Source of variation	D.F.	S.S	M.S	F
Replication	4	877.19	219.30	1.42 ns
Week	47	22916.70	487.59	3.16**
Error	188	29008.41	154.30	
Total	239	52802.30		

c.v. = 16.4%

** Significant at P = 0.01 ; ns - not significant

b. Minimum solar intensity

Source of variation	D.F.	S.S	M.S	F
Replication	4	182.31	45.58	< 1
Week	47	16056.33	341.62	5.08**
Error	188	12651.29	67.29	
Total	239	28889.93		

c.v. = 46.0%

** Significant at P = 0.01

c. Pump discharge

Source of variation	D.F.	S.S	M.S	F
Replication	4	0.32	0.08	< 1
Week	47	53.58	1.14	3.62**
Error	188	59.19	0.31	
Total	239	113.09		

c.v. = 28.9%

** Sinificant at P = 0.01

Efficiency of Photo Voltaic Pumping System

Power input to PV panel = Cell area (m^2) x solar radiation (Wm^{-2})

Electrical power output of PV panel = Voltage x Current

PC Efficiency = Electrical power output / Power input

This Efficiency of electronic invertor to convert DC current to AC current was 95% according to the manufacturer's specifications. The motor efficiency was assumed as 95%.

Power input to the pump = Electrical power output of the PV panel x Efficiency of Inverter and motor

Power output from the pump = (Q x H x 736) / (75 x 3600)

Where Q = Pump discharge / h^{-1}

H = Total pump head, m

Pump efficiency = Water hp / Electrical input power

System efficiency = PV efficiency x Pump efficiency

The data collected were also pooled month-wise with daily minimum and maximum solar radiation intensity, total pump running hours per day and discharge during the period. The data was classified season-wise, namely summer (March to May), Southwest monsoon (June to September), Northeast monsoon (October to December) and winter (January to February). The maximum and minimum solar radiation intensity observed during the period, total number of days pumped during the season, total hours worked and water pumped during the season, average water discharge per day, average water flow per hour, maximum and minimum water flow per day were calculated.

RESULTS AND DISCUSSION

The analysis of variance (Table 1) on week-wise maximum solar intensity showed that there was significant variation between the weeks. This is very much anticipated became of the seasonal variations. The mean comparison (Duncan's Multiple Range Test) showed that the mean maximum solar intensity was highly variable between the weeks. Very few comparable means were observed in the month of August.

Although the analysis of variance on minimum solar intensity (Table 1) showed significant

Table 2. Efficiency of photo voltaic pumpin system

Time	Solar intensity (mWcm^{-2})	Pump discharge (/h^{-1})	Power input to panel (W)	Elec. Power output from panel (W)	Power input to pump (W)	Power output from pump (W)	Pump efficiency (%)	PV efficiency (%)	System efficiency (%)
8.30	40	1040	4800	215.52	193.97	85.05	43.85	4.49	1.97
9.00	52	1700	6240	321.36	289.22	129.02	44.61	5.15	2.30
9.30	56	1840	6720	350.11	315.10	150.47	47.75	5.21	2.49
10.00	62	2290	7440	409.20	368.28	187.27	50.85	5.50	2.80
10.30	72	3180	8640	535.68	482.11	260.05	53.94	6.20	3.34
11.00	44	1220	5280	250.80	225.72	99.77	44.20	4.75	2.10
12.00	82	3420	9840	678.96	611.06	279.68	45.77	6.90	3.16
12.30	86	3560	10320	726.53	653.88	291.13	44.52	7.04	3.13
13.00	70	3080	8400	516.60	464.85	251.87	54.18	6.15	3.33
13.30	62	2210	7440	408.46	367.61	180.73	49.16	5.49	2.70
14.00	46	1310	5520	266.62	239.96	107.13	44.64	4.83	2.16
14.30	58	1810	6960	374.45	337.00	148.02	43.92	5.38	2.36
15.00	42	1080	5040	229.82	206.84	88.32	42.70	4.56	1.95
15.30	38	940	4560	189.70	170.73	76.87	45.02	4.16	1.87
16.00	32	810	3840	142.08	127.87	66.24	51.80	3.70	1.92

variation between weeks, the mean comparison showed that the week means were almost on par in all the months of the year except in the winter of December and January.

The solar pump discharge is a dependent variable relying on the solar intensity of the day, and was also analysed to find out the mode of variability in comparison with that of solar

Table 3. Seasonwise performance of solar submersible pump

Season	Solar radiation Max (mWcm-2)	Solar radiation Min	Total working days (no)	Total discharge (l)	Total working hours (h)	Average discharge in a day (l)	Average discharge in an hour (l)	Discharge in an hour Max (l)	Discharge in an hour Min (l)
Winter Jan-Feb	94	10	40	7,55,300	340	18,883	2221	3059	318
Summer Mar-May	100	6	75	13,21,670	593	17,649	2229	3356	978
S.W.M June-Sep	100	2	84	11,62,640	682	13,834	1704	3076	28
N.E.M. Oct-Dec	96	4	64	9,42,325	528	14,708	1783	2818	118

S.W.M - South West Monsoon

N.E.M - North East Monsoon

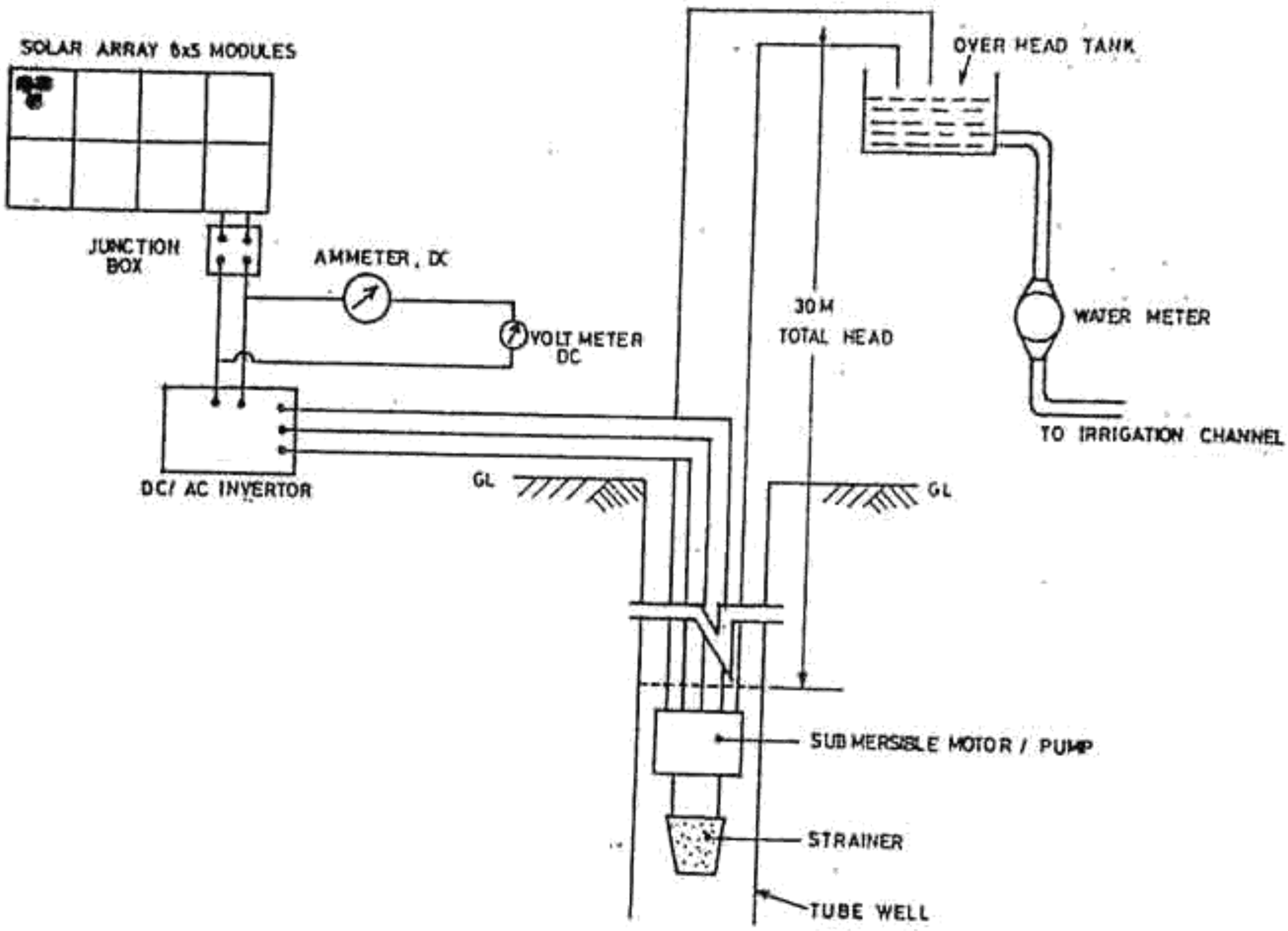

Fig. 1. Solar Photo-voltaic Submersible pump

intensity. The analysis of variance (Table 1) indicated significant variation of pump discharge between the weeks. The mean comparison showed high variability between the weeks except for the months from June to August. This seems that the pump discharge depends mainly on the maximum solar intensity rather than on the minimum solar intensity.

To bring out more evidence on the dependence of pump discharge on the maximum and minimum solar intensities, a regression analysis was attempted on the weekly observations.

The regression was of the form

$$Y = -0.3224 + 0.024 \text{ (maximum solar intensity)} + 0.026 \text{ (minimum solar intensity)}$$

$R^2 = 0.64^{**}$

The regression was significant inferring that there is a linear relationship between the solar intensity and pump discharge. The 't' test showed that all the coefficients are significant and hence the hypothesis that minimum solar intensity does not contribute towards pump discharge has been disproved.

The negative intercept proved that a minimum solar intensity is required for operating the solar panel in order to give a pump discharge. Substituting Y=0 in the above equation and assuming that the maximum and minimum solar intensity on a day are equal ($X_1 = X_2$)

$$X_1 = 6.5 \text{ mWcm}^{-2}$$

This is the minimum solar intensity above which the pump will start functioning.

Table 4. Predicted water flow in solar, submersible pump

Season	Month	Sunshine duration (hday^{-1})	Average dischage (lh^{-1})	Predicted discharge (lday^{-1})
Winter	January	8.6		19100
	February	9.5	2221	21100
	March	9.8		21766
Summer	April	8.9		19838
	May	7.8	2229	17386
	June	6.0		13374
S.W.M.	July	4.5		7668
	August	5.9	1704	10053
	September	7.1		12098
N.E.M.	October	6.5		11590
	November	6.8	1783	12125
	December	7.6		13551

S.W.M - South West Monsoon

N.E.M - North East Monsoon

The data for the month of April were pooled and PV efficiency, pump efficiency and system efficiency were calculated (Table 2). The result revealed that the discharge increased with the increase in solar intensity. The efficiency of PV system in converting solar energy into direct electricity varied from 3.7 to 7.04 per cent (Chamey *et al.*, 1992 and Sharma *et al.*, 1995). The pump efficiency varied from 42 to 54 per cent, but maintained around 43 per cent (Mehmoud and Marwan, 1993). The variation in system efficiency was 1.85 to 3.3 per cent. It was also observed that the pump efficiency was slightly lower, when the solar intensity was the highest (Laxsom and Durongkaveroj, 1994 ; Fett *et al.*, and Koner *et al.*, 1987) as that of pump efficiency.

The season-wise performance and predicted water flow in the solar submersible pump are presented in table 3 and 4 respectively. The results showed that the pump discharge was 1700/h^{-1} during the two monsoon periods and 2200/h^{-1} in summer. The predicted water flow varied from 19000 - 21.700/day^{-1} in winter and 17,300 - 20,000/day^{-1} in summer. The same during Southwest and Northest monsoon were 7600 - 12,000 and 11,5000 - 13,500/ day^{-1} respectively.

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