Derive the Relationship between the Solar Radiation and Discharge in Solar Pumping System

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Abstract -- The ever increasing mismatch between the demand and supply of energy in general and electricity in particular, is posing challenges to farmers located in remote area. Scarcity of electricity coupled with the increasing inerrability of monsoon rains is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. However, the cost of using diesel powering pump set for irrigation are often beyond the means of small and marginal farmers .Therefore the utilization of renewable energy become a crying need for today. Among different type of renewable sources, solar energy has great prospectus for utilization in electricity generation. Hence there is need to use solar pv system and environment friendly, low maintenance, solar photovoltaic system (SPV) provide new possibility for pumping irrigation water. The reading of maximum and minimum temperature were taken 30 minutes interval during sunshine period at both selected sites and analyzed.. During the morning session incident solar radiation minimum. So that resulting discharge from both the pump were minimum. From morning to afternoon pump discharge increase linearly as solar radiation increase. During the after session the incident solar radiation were maximum hence, the discharge of pump also maximum. After afternoon session pump discharge decrease of solar radiation decrease and found to be minimum at 5.00 pm. The analysis concludes that the pump discharge is directly proportional to incident solar radiation.

Indexed Terms- Solar Photovoltaic (SPV) pumping system, incident solar radiation.

I. INTRODUCTION

A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for the vast Agril/rural population of India. The ever increasing mismatch between the demand and supply of energy in general and electricity in particular, is posing challenges to farmers located in remote areas. The scarcity of electricity coupled with the increasing unreliability of monsoon rains is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. However, the costs of using diesel powering pump sets for irrigation are often beyond the means of small and marginal farmers. Consequently, the lack of water often leads to damaging of crop, thereby, reducing yields and income. Issues like energy and global warming are some of the biggest challenges for humanity in the 21st century. Therefore ensuring energy resources and minimize the global warming; the utilization of renewable energy becomes a crying need for today. Among different types of renewable resources, solar energy has great prospect for utilization in electricity generation. Hence, there is need to use solar PV system; an environment-friendly, low-maintenance, solar photovoltaic (SPV) pumping systems provide new possibilities for pumping irrigation water.

At present, the industrial users cross-subsidies the agricultural consumers to the extent of around Rs-6,980 crore per year; in addition, the state government bears an additional subsidy burden of around Rs 3,500 crore for about 40 lakh metered and unmetered agricultural pumps, which make up for around 23% of the state's power demand. Around 2 lakh fresh agriculture connections are added every year. Taking these pumps off the grid will eventually reduce the industrial power tariffs by around Rs 1 per unit. But pumps with a massive installed capacity including those used in lift irrigation schemes will not be replaced .Farmers' tariffs depend on the installed horse power (HP) capacity of their pumps and officials say under-reporting of this capacity to ensure lower bills is rampant with a poor payment culture. Agricultural consumers pay just Rs3, 014 annually for a 3 HP pump; the state government pitches in with the balance amount in the Rs14, 098 total bill. For a 5 HP pump, the farmer pays Rs7, 669 of the Rs23, 336 bill. A large number of pumps in the state are 5 HP ones, said officials from the Maharashtra State Electricity Distribution Company Limited (Maha Vitaran)."The plan, the largest of its kind so far, will involve the replacement of 5 lakh conventional pumps annually with solar-powered

ones. This is the government's vision for ensuring that farmers, even in areas where transmission lines cannot be laid, can generate power for watering their farms. This will also bring down tariffs for industries by reducing the cross-subsidy," said an official from the chief minister's office (CMO). He added that they would also get subsidy from the union ministry for new and renewable energy (MNRE) which, along with the state will contribute an equal amount of 30% for the pumps with the remaining being met from debt and the farmers' contribution. For this study following objectives were decided

1. To study of solar PV water pumping system.
2. To determine the relationship between pump discharge with respect to different solar radiation.

To compare solar pump system to other conventional systems.

II. MATERIALS AND METHODS

Material & System Components:

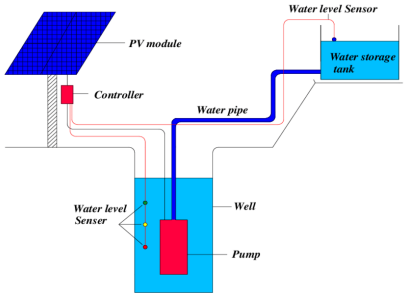

Fig. 1: Schematic view of solar pumping system with PV-Array

1) Solar PV array: The Solar PV array is a set of photovoltaic modules connected in series and possibly strings of modules connected in parallel.
2) Controller: The Controller is an electronic device which matches the PV power to the motor and regulates the operation of the pump according to the input from the solar PV array
3) Water source: It is a Farm pond.
4) Pump set: Pump sets generally comprise of the motor, which drives the operation and the actual pump which moves the water under pressure.
5) DC Motor: The DC Motors with permanent magnet are generally more efficient. DC Motors may be with or without carbon brushes. DC motors with carbon brushes need to be replaced after approximately every 2 years. Brushless designs require electronic commutation. Brushless DC Motors are becoming popular in the solar water pumps.
6) Submersible pump: Placed in the water source.
7) Water meter: It is used to measure the amount of flow of water in m^3
8) Thermometer: It is used to measure air temperature.

The site is to be selected of two farmers in sinnar taluka of Nashik district.

Table 1: Site selection

Items	**Site 1**	**Site 2**
Name of site	Kundewadi, Sinnar, Nasik (Maharashtra)	Panchale, Sinnar, Nasik (Maharashtra)
Latitude	19.8530˚ N	19.8762539˚ N
Longitude	74.0006˚ E	74.2157235˚ E
Name of farmer	Mrs Chandrabhagabai Vitthal Kurhade	Mr. Thorat Pandharinath Vithhal
Water source	Farm pond(65 lakh litre)	Farm pond(70lakh litre)
Pump capacity	3Hp submersible	5Hp submersible
Solar plates	2 panels, 12 Arrays.	3 panels, 16 Arrays

FORMULAE:-
To determine the solar radiation of selected site.
R_s= [0.16($T_{max} - T_{min}$) ^0.5]*R_a
Where,
Rs:-solar radiation,
T_{max} :-maximum air temperature, °c
T_{min} :-minimum air temperature, °c

R_a:-extra-terrestrial radiation ($\frac{MJ}{m^2}$)

$R_a=(\frac{24*60}{\pi})G_{sc}*d_r[\omega s.\sin\varphi.\sin\delta+\cos\varphi\cos\delta.\sin\omega s$

]

Where,

G_{sc} :-solar constant, (0.0820 MJ.$m^{-2}.min^{-1}$)

φ : -latitude (radian)

$d_r=1+0.33\cos(\frac{2\pi}{365}*J)$

Where,

d_r :-invers relative distance from earth to sun

J:-calendar day of year

$\delta= 0.409\sin(\frac{2\pi}{365}*J-1.39)$

Where,

δ= solar declination (radians) and

$\omega_s=\arccos(-\tan(\varphi)\tan(\delta))$

Where,ω_s =sunset hour angle (radians)

To compare the PV water system and other systems The following parameters to be consider:

1) Capital Cost
2) Maintenance cost
3) Operating Cost
4) Life Period
5) CO2 emission
6) Harmful to nature
7) Government Subsidy availability

III. RESULTS AND DISCUSSION

Through the obtained experimental results of the selected Solar Photovoltaic Pumping System, a comparative study is carried out to determine the total performances of pump discharge with respect to radiation. Variation of discharge of solar pump with solar radiation at different times of a day was tested at two different sites in Nasik district.

- Site 1: Kundewadi, Sinnar: Readings are taken on 31st August 2016 from 10 AM to 5 PM with 30 minutes interval as follows:

Table 2: Incident solar radiation and discharge of 3hp pump at various temperatures

TIME	Tmin (°C)	Tmax (°C)	DISCHARGE (lps)	RADIATION(kw/m^2)
10 AM	25	26.8	7.4	10.723
10:30AM	26.1	28	7.50	11.016
11 AM	26.7	28.7	7.53	11.303
12 PM	30	32.7	7.56	13.132
12:30 PM	30.3	33.10	7.60	13.373
1 PM	30.1	35.10	7.84	17.871
1:30 PM	30.8	34.8	7.83	15.984
2 PM	31.1	34.1	7.81	13.844
2:30 PM	31	33.4	7.77	12.381
3 PM	30.5	32	6.60	9.788
3:30 PM	30.3	31.6	6.44	9.112
4 PM	30	31	6.26	7.992
4:30 PM	29.4	29.9	6.24	5.651
5 PM	28.7	29	6.08	4.377

The graph is plotted between solar radiation and discharge obtained from 3HP pump as shown below:

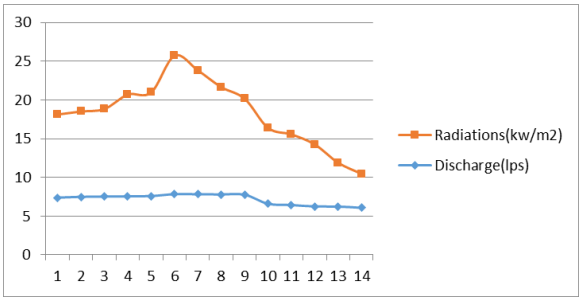

Fig .2: Graphical representation of incident radiation and discharge.

From above graph it can be seen that maximum discharge i.e, 7.84 lps was obtained when the incident solar radiation was maximum i.e. 17.871 kw/m^2. Similarly; minimum discharge i.e; 6.08 lps was obtained when the incident solar radiation was minimum i.e; 4.373 kw/m^2.Also, the average solar radiation of site was found to be 11.18 kw/m^2 and the average discharge of 3 HP pump was found to be 7.17 lps.

So that we can say that the discharge of solar water pump is directly proportional to the incident solar radiation.

- Site 2: Panchale, Sinnar

Readings are taken on 24th November 2016 from 11 AM to 5 PM with 30 minutes interval as follows:

Table 3: Incident solar radiation and discharge of 5hp pump at various temperatures

TIME	Tmin (°C)	Tmax (°C)	DISCHARGE (lps)	RADIATION (kw/m^2)
11:30 am	29	30.4	13.61	9.450
12 pm	29.5	31.7	13.72	11.846
12:30 am	29.5	32	14.34	13.601
1 pm	31	34.3	14.44	14.507
1:30 pm	32	34.4	13.78	12.372
2 pm	32.2	34.5	13.72	12.118
2:30 pm	32.1	33.8	13.61	10.413
3 pm	32	33.1	12.94	8.376
3:30 pm	30.5	31.5	12.22	7.992
4 pm	30	30.9	11.22	7.576
4:30 pm	29	29.6	9.72	6.186
5 pm	27	27.5	7.11	5.647

The graph is plotted between solar radiation and discharge obtained from 5HP pump as shown below:

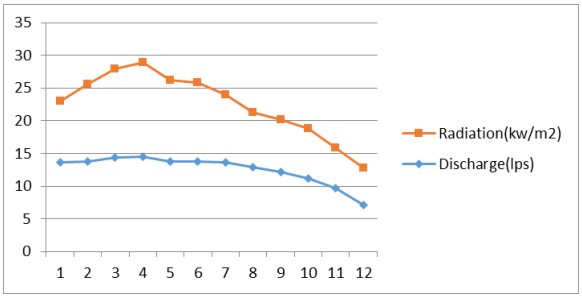

Fig .3: Graphical representation of incident radiation and discharge.

From above graph it can be seen that maximum discharge i.e.14.44 lps was obtained when the incident solar radiation was maximum i.e. 14.507kw/m^2. Similarly; minimum discharge i.e; 7.11 lps was obtained when the incident solar radiation was minimum i.e; 5.647 kw/m^2. Also, the average solar radiation of site was found to be 10 kw/m^2 and the average discharge of 5 HP pump was found to be 12.53lps.

So that we can say that the discharge of solar water pump is directly proportional to the incident solar radiation.

Table 4: Economics of solar pv water pumping and diesel powered water pumping system.

Parameter	Cost(in rupees)
Cost of 1 Hp diesel powered pump set	25000
Cost of equivalent Solar PV water pump(unsubsidized) No. of operating hours per year (200days * 5 hours/day)	200000
Cost of diesel/liter	60
Fuel consumption/hr. of 2kVA DG set	0.75
Average increase in fuel prices per annum	5%
Maintenance cost/year for diesel pump	2000
Maintenance cost/year for solar pump	500
Life cycle period (in years)	10

Table 5: Comparison of cost between solar pump and diesel pump

Item No.	Capital cost(in rupees)	Net Present Maintenance Cost(in rupees)	Net Present Fuel Cost(in rupees)	Total(in rupees)
SPV Pump	200,000	3,072	Nil	203,072
Diesel Pump	25,000	12,289	278,993	316,282

IV. CONCLUSION

The comparative study was carried out between the solar pump discharge and solar radiation so the following conclusion are concluded.

1) During the morning session the incident solar radiations were minimum. So that the resulting discharge from both the pumps were minimum. From morning to afternoon pump discharge increases linearly as solar radiation increases.
2) During the afternoon session the incident solar radiations were maximum hence, the discharge of pumps also maximum. After afternoon session pump discharge decreases as solar radiations decreases and found to be minimum at 5pm.
3) In the first site sinner taluka's Kundewadi village at the time of morning time i.e. 10.00 am radiation is 10.723 kw/m^2 and discharge for that time is 7.4 lps, at afternoon the radiation is 15.894 kw/m^2 and discharge for this radiation is 7.83 lps and evening i.e.5pm the radiation is 6.08 kw/m^2 and discharge for this radiation is 4.377lps.
4) In the second site of sinner taluka's of Panchale Village at time of morning the radiation is 9.450kw/m^2 and discharge for the morning time is 13.6lps , at afternoon the radiation is 12.37kw/m^2 and the discharge is 13.78 lps and at evening session i.e. 5pm the radiation is 7.11kw/m^2 and the discharge is 5.67 lps
5) The analysis concludes that the pump discharge is directly proportional to incident solar radiations.

REFERENCES

[1] D. Waddington, A. Herlevich, Evaluation of Pumps and Motors for Photovoltaic Water Pumping Systems, Solar Energy research institute for the US depart-ment of energy, Colorado, USA, 1982. SERI/TR-214e1423.

[2] Hadj Arab, F. Chenlo, K. Mukadam, J.L. Balenzategui, Performance of PV water pumping systems, Renew. Energy 18 (1991) 191e204

[3] S.A. Alajlan, M.S. Smiai, Performance and development of PV - plant for water pumping and desalination for remote area in Saudi Arabia, Renew. Energy 8 (1996) 441e446.

[4] M. Kolhe, J.C. Joshi, Performance analysis of directly coupled photovoltaic electro-mechanical systems, Proc. Inst. Mech. Eng. Part A J. Power Energy 216 (6) (2002) 453e464.

[5] P.C. Pande, A.K. Singh, S. Ansari, S.K. Vyas, B.K. Dave, Design development and testing of a solar PVpump based drip system for orchards, Renew. Energy 28 (2003) 385e396

[6] I. Odeh, Y.G. Yohanis, B. Norton, Influence of Pumping Influence of pumping head, insolation and PV array size on PV water Pump performance, Sol. Energy 80 (2006) 51e64.

[7] M. Abdolzadeh, M. Ameri, Improving the effectiveness of a photovoltaic water pumping system by spraying water over the front of photovoltaic cells, Renew. Energy 34 (2009) 91e96.

[8] Abdelmalek Mokeddem, Abdelhamid Midoun, D. Kadri, Said Hiadsi, Iftikhar A. Raja, Performance of a directly-coupled PV water pumping system, Energy Convers. Manag. 52 (2011) 3089e3095.

[9] M. Al-Smairan, Application of photovoltaic array for pumping water as an alternative to diesel engines in Jordan Badia, Tall Hassan station: case study, Renew. Sustain Energy Rev. 16 (2012) 4500e4507.

[10] M. Benghanem, K. O. Daffallah, A. A. Joraid, S. N. Alamri, A. Jaber, 2013. "Performances of solar water pumping system using helical pump for deep well: a case study madinah, Saudi Arabia." Energy Conversion and Management, January2013

[11] A.A. Setiawan, D.H. Purwanto, D.S. Pamuji, N. Huda, Development of a solar water pumping system in Karsts Rural Area Tepus, Gunungkidul through student community services, Energy Procedia 47 (2014) 7e14.