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Development and Evaluation of Solar Battery Charger Coupled with SPV Pumping System

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The solar battery charging station for charging of various farm equipment viz., tractor, power tiller, grass cutter, etc. using 12 V and 24 V DC systems was developed and evaluated. The charging station is suitable for coupling with 0.5 hp SPV pumping system suitable for lifting the shallow depth water in remote area. The performance of SPV system for water lifting coupled with charging station was evaluated. The dual application of SPV pumping system and battery charging system facilitates the full utilization of sunshine hours for useful work.

Introduction

Water is an essential input in any agricultural production system to achieve the desired level of productivity. Majority of the farmers grow their *rabi* and summer crops by lifting the water from wells, tanks, natural streams, check dams, and canal. In India, lifting water with electric motor does most of the irrigation or diesel engine operated pumps. In most part of country is facing irregular supply of electricity. Similarly the diesel as a natural fuel is becoming more and more scares with the volatility in prices. In the remote areas of the country the availability of either of these two major energy sources is uncertain. Thus, the use of both the energy sources is becoming unreachable for the farmer to irrigate their fields. It emphasizes the use of an alternate energy sources for irrigation and is one of the main infrastructure requirement for the overall development of agriculture has inevitable. Solar photovoltaic (SPV) pumping system may be the best solution to the problem as it is direct utilization of solar energy.

The Konkan region of Maharashtra is a long and narrow strip between $15^{0}3'$ N and $20^{0}20'$ N latitude and $72^{0}7'$ E to $74^{0}30'$ E longitude having latitude up to 500 m with most of the part is hilly region and adverse topography and the region receives rainfall of 2000 to 3500 mm. The adverse topography with dense forest in the region mainly causes the problem of installation of conventional electric grid as well as interrupts the regular electricity supply due to heavy wind and rainfall. In this content the solar photovoltaic pump with low or medium head can be very much suitable for lifting the water from the perennial streams to certain elevation. This system can also be used for lifting the water from shallow ground water. The solar energy in Konkan region is available for 7 to 8 months in a year with an average 6 to 8 bright sunshine hrs/day and intensity of 450 to 600 cal/cm^{2}day that can be utilized for SPV pumping systems.

Based on the cropping system, type of crop, crop duration and irrigation interval, the solar pumping system cannot operate to its full extend hence reduce the economic benefits. During the ideal condition (no water requirement) of SPV pumping system, the huge converted power from SPV panel was wasted without any useful work. It is necessary to utilize the power available during ideal condition for useful gain. The available power from SPV system can be utilized for battery charging for Inverters, small equipments, lighting, vehicles etc with suitable charging system. The effective utilization of SPV pumping system for battery charging will add the additional benefit to the user.

Materials and Methods

The study was conducted to evaluate the 0.5 hp capacity SPV pumping system for water lifting at low head and evaluation of coupled battery charging station.

SPV pumping system and experimental layout

The experimental layout as shown in Figure 1 consists of solar photovoltaic array of 20 panels (100 X 40 cm size each), with a peak output ranges between 250-300 W capacity, a monoblock centrifugal pump with suction and delivery pipe and water storage and measuring tank. The U-tube manometer was connected to delivery pipe to measure the operating pressure of pump. Centrifugal pump was used to lift the water from a water tank using solar energy. A metallic tank of 50 lit. capacity was used for discharge measurement of the lifted water. The observations of discharge at an interval of one hour from 8.00 am. to 5.00 pm. The experimental layout and various components of SPV pumping system is shown in Figure 1.

Determination of efficiencies

Data collected on incoming solar energy, array output and pump discharge have been used to evaluate the conversion efficiency and pumping efficiency.

Conversion efficiency of SPV array

The conversion efficiency shows how effectively the solar energy converts the solar radiation in to an electrical energy and it is a function of the purity level of basic material, workmanship in its fabrication and its sensitive to temperature.

Conversion efficiency can be calculated as

$$\text{Conversion efficiency (\%)} = \frac{\text{Array Output}}{\text{Total incoming energy}} X\ 100$$

The total incoming energy can be calculated by multiplying the incoming energy (watts/ sq. m with total panel area in m^2.

Incoming energy (W/m^2) = *Total number of cells x Panel area of each cells x total number of modules*

The panel area was found to be 3.26 m^2.

Pumping efficiency of SPV array

The pumping efficiency can be determined as

$$\text{Pumping Efficiency} = \frac{\text{Water Horse Power (W)}}{\text{Array out put (W)}} \times 100$$

The Water power can be calculated as

Water horse power (W)=

$$\frac{\text{Total head (m)} \times \text{Pump discharge (lit/sec)}}{75} \times 746$$

Solar PV operated battery charger

The solar PV operated charging station coupled with water pumping was developed. The SPV based charging station consist of various components as

SVP pumping system

It is used to convert solar energy into electrical energy. The SPV pump having solar panel (72 V, 5 A current with max. output-375 wp) will act as a main source of energy for battery charging during ideal condition.

Main charger

It consists of electronic circuit which is used to regulate the power supply at fixed voltage. It will charge the main battery bank (48 V, 3A) and prevent the reverse flow from the battery to the panel during night time.

Battery bank

A battery bank which is charged by the main charger will act as a charge reservoir for uninterrupted power supply at fixed voltage.

Terminal charging units

It consist of an electronic circuit which provide the constant supply of 12 V, 5 A and 24 V, 4 A simultaneously for charging the two different batteries of 12V and 24 V using the two way switch. The layout of SPV pumping system and coupled solar battery charger is shown in Figure 2.

The electronic circuit is developed by using the component as shown in table 1 and 2 for DC to DC converter from 48 V/3A to 12V/5A and 48 V/3A to 24V/4A along with charging and discharging controller and protection for battery bank and end use appliances.

The solar battery charger was tested for charging the 12 V battery and 24 V batteries which are commonly used for various applications. The solar charger was also tested for time required for charging the battery bank of 4 nos. 12 V connected in series.

Results and Discussion

The conservation efficiency of SPV unit is the ability of solar photovoltaic cells to convert the light part of solar insolation into electricity. The conversion efficiency of solar panel gives an input to the solar photovoltaic pumping system thus it was evaluated for the daytime operation during *Rabi* season. Solar radiation and other climatic parameters, being the main source of input to solar photovoltaic, the combined effect of all these parameters on conversion efficiency of solar panel was evaluated by multiple regression analysis and is illustrated in Figure 3.

Conversion efficiency found to be varying from 5.67% to 17.61%. Initially the conversion efficiency was higher and it declines as the elapsed time progressed and again it was seen steadily increasing up to 4.00 p.m.

It was highest at the evening (5.00 p.m.). The most influencing parameter in isolation among considered was found to be solar insolation.

Evaluation of solar photovoltaic pump characters

The solar photovoltaic pump was evaluated for the discharge at lower and higher heads and the pump characteristics viz. pump discharge, pump efficiency and operation time were determined and are discussed in the following sections.

Table.1 Electrical circuit components used for battery charging

1-SL100 R1-4.7k **T2-BC148 R2-200 ohm** **VR1-4.7K R3-47 ohm** **C2-100 uf/25v R4-10k** **C1-470uf/25v R5-10k** **Z1-1w zener reqd voltage**	**D1-BYV79 C1-680p** **R1-1K C2-470u/35v** **R2-1ohm/4w C3-470u/35v** **R3-1ohm/4w C4-1000uf/16v** **R4-18k T1-BUZ10** **R5-1.2k IC 1-TLO82/TL497A** **P1-10k L1-30uH**

Table.2 Battery charger circuit

R1-1.8k **R2-1.8k** **R3-1.8k** **R4-3.3k** **R5-330 ohm** **R6-3.3k** **P1-4.7k**	**L1-LED overcharge** **L2- LED cut off** **S1-SCRTY1016** **D1-1N4001** **Z1-8.2 V** **C1-100 uf/50v** **CB-Ckt.braker** **R-Relay coil**

Table.3 Charging of battery bank (4Nos, 12V each connected in series)

Time	Sun intensity, luxx100	Voltage level
09.00 am	695	10 V
10.00 am	870	17 V
11.00 am	1084	24 V
12.00 pm	1135	35 V
01.00 pm	1270	40 V
02.00 pm	1190	45 V
03.00 pm	908	48 V
04.00 pm	665	51 V
05.00 pm	335	51.5 V

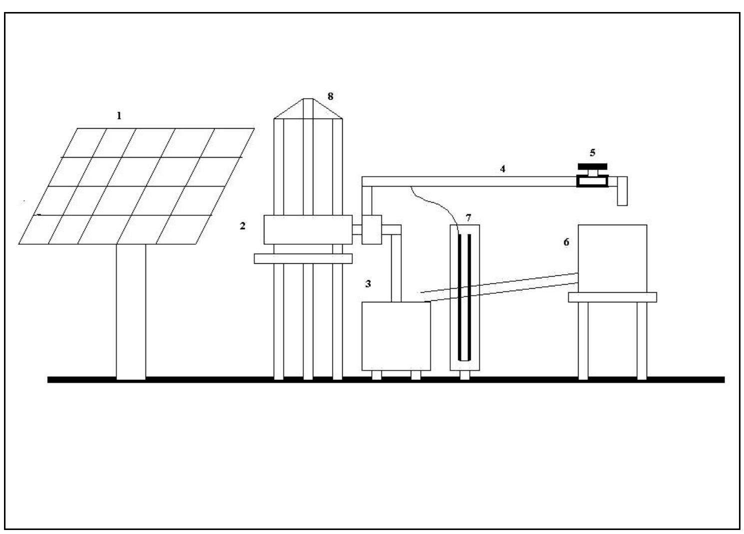
Table.4 Charging of 12 Volt, 17 AH sealed lead acid battery

Time	Sun intensity, lux x100	Voltage level
09.00 am	324	05.60 V
10.00 am	745	07.5 0V
11.00 am	965	10.45V
12.00 pm	1114	11.98 V
01.00 pm	1172	12.00 V
02.00 pm	1060	12.05 V
04.00 pm	570	12.06 V

Table.5 Charging of 24 Volt (12V, 17 AH 2 Nos. connected in series) Battery

Time	Sun intensity, lux x100	Voltage level
12.00	1075	17.00 V
01.00 pm	1175	21.60 V
02.00 pm	1062	23.50 V
03.00 pm	835	23.7 V
04.00 pm	540	23.80 V
05.00 pm	435	23.90 V

Fig.1 Experimental layout of SPV pumping system



1. Solar Panel
2. SPV Operated Pump
3. Water Storage Tank
4. Delivery Pipe
5. Valve
6. Measuring Tank
7. Manometer
8. Stand

Fig.2 SPV pumping system coupled with battery charger

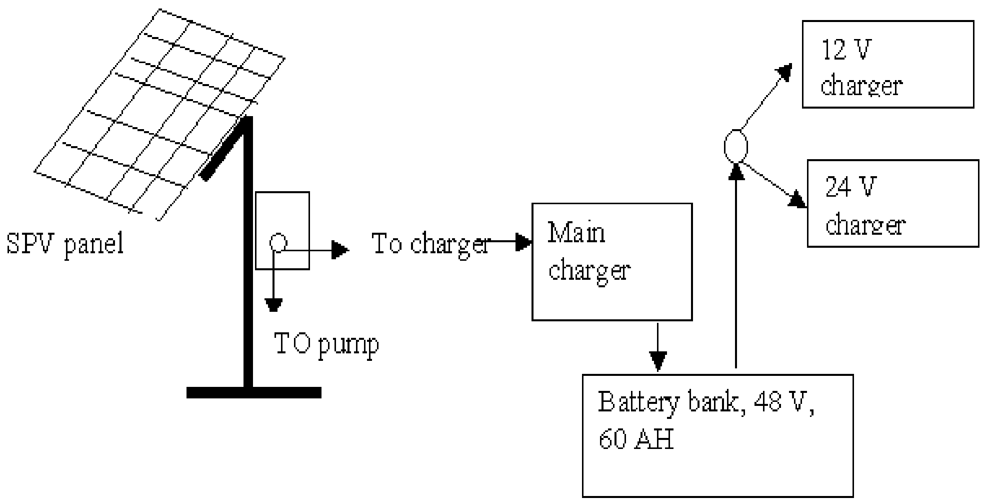
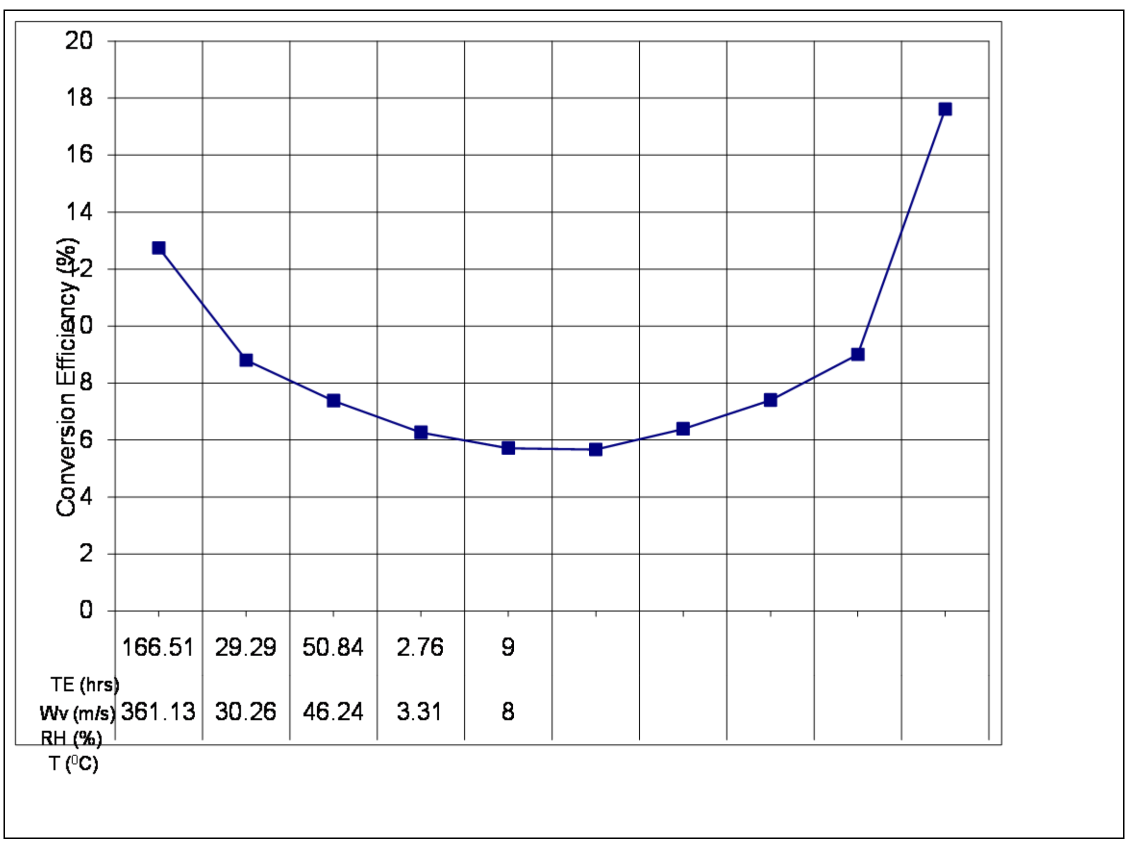
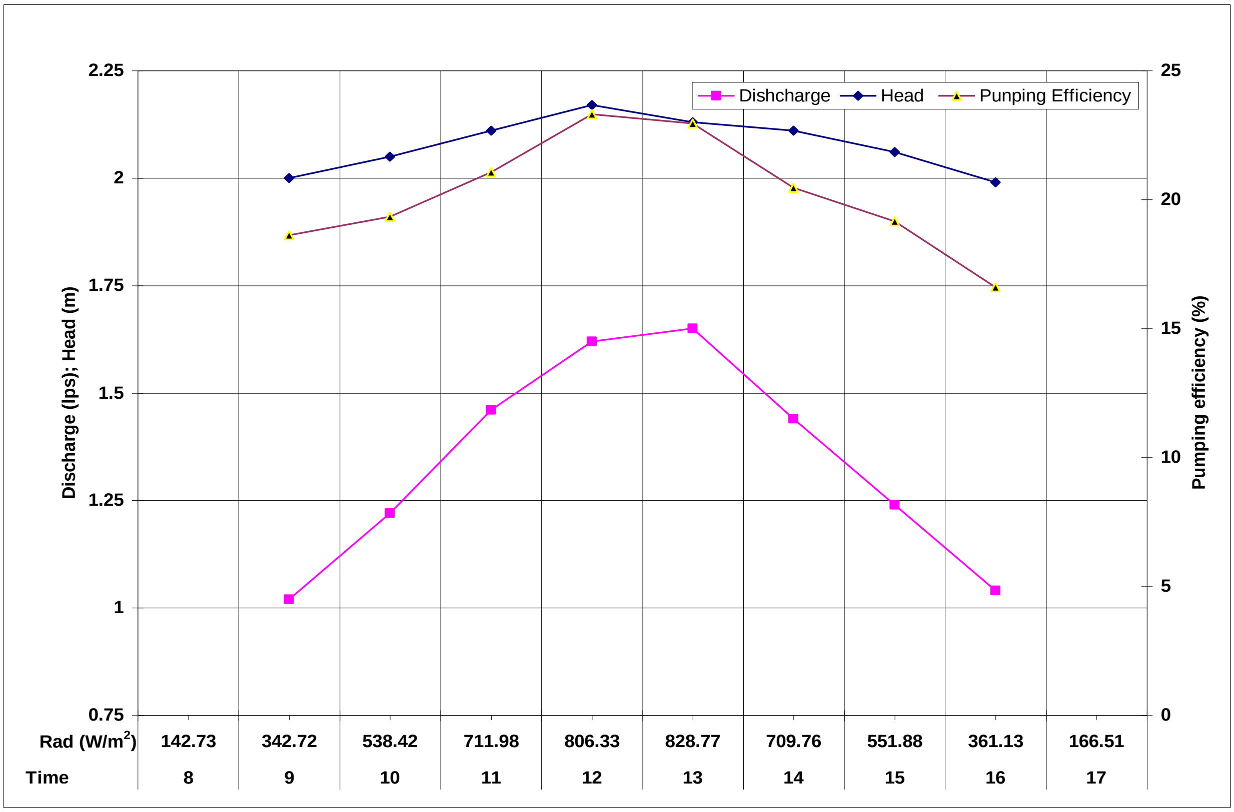


Fig.3 Combined effects of radiation, temperature, relative humidity, wind velocity and elapsed time on conversion efficiency



Note: Elapsed time as ‘0’ indicates ‘8.00 a.m.’ and ‘9’ indicates ‘5.00 p.m.’

Fig.4 Pump characteristics against time for lower head operation



Pump operated at lower head

During the morning (8.00 to 9.00 a.m.) and evening (4.00 to 5.00 p.m.) hours of operation the discharge was very low, however the conversion efficiency during these hours was higher so it was omitted. During the operation period from 9.00 a.m. to 4.00 p.m., it is seen that from Figure 4 at lower head operation, the total head lifted by pump was approximately constant with an average of 2.07 m and while the discharge was found to be varying from 1.02 to 1.65 lit/sec with an average value of 1.394 lit/sec.

Pumping efficiency for lower head remained almost constant with slight increasing trend from 11.00 a.m. to 12.00 noon and decreasing thereafter. Increasing trend may be due to increased radiation and temperature during that period. Pumping efficiency was seen to be ranging from 19.15% to 23.3% with an average of 20.03%.

Testing of solar battery charger

The result obtained from testing of the battery charger is depicted in the tables 3, 4, and 5.

It is observed that the average time required for charging the battery bank 10 V discharge level to 51 V full charged level is about 08 hours during the bright sunshine hours. The average time required for charging the 12V, 17 AH sealed lead acid battery from 5.6 V discharge level to 12.06 V full charge level is about 06 hours. The average time required for charging the 24 V 17 Ah x 2 nos connected in series from 17 V to 23.9 V is about 05 hours. The overall cost of charger is found to be Rs. 9000/- without battery bank.

In conclusion, the solar battery charger works satisfactorily. The avg. time required to charge the 12 V, 17 AH battery and 24 V (12V, 2Nos in series) is about 06 hours and 05 hours respectively. The total cost of the charger is about Rs 9000/- without battery bank.

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