Development And Performance Testing Of Solar Operated Insecticide And Pesticide Agro Spraying System

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Abstract: This paper represents the development and performance analysis of Solar operated Spraying system. Generally in the agricultural field, traditional conventional techniques like hand operated and fuel operated sprayer system for spraying pesticides have been used which is not eco-friendly, less labour productivity and low efficiency. These tools uses diesel as fuels which is harmful for the environment and also do increases the operating and maintenance cost. This motivates us to design and fabricate real-time product which is operated by solar energy. The main objective of this research is to design and fabricate the solar powered agricultural pesticide sprayer by considering parameters like desired spraying capacity, low weight, low cost, user-friendly nature, high operating time and for faster coverage of area. Mathematical models were developed after adopting suitable assumptions for calculation of power of the motor and sizing of battery, charge controller, solar panel required for spraying a known quantity of fluid. The parts required for the system had been selected by solving for known inputs values and considering their availability in the market. The maximum discharge at outlet of DC Pump, efficiency of pump had been calculated by taking different discharge at outlet of the pump. Further by using 12 Volt Led light, it can be operated in night mode and also is to reduce back pain of human being by keeping the tank in backside.

Keywords: Solar panel, sprayer, charge controller, battery, DC pump.

I. INTRODUCTION

Photovoltaic (PV) energy is cheap, freely available, environmental friendly which makes it an alternative source to Conventional sources (such as coal, petrol etc).Photovoltaic energy can meet the present demand of electricity and requires less operational and maintenance cost. Therefore an efficient solar operated spraying machine was fabricated which consists of mainly solar Panel, Maximum power point Tracking Technique Charge controller, Battery, DC (Direct current) Pump, MCB switch, agro sprayer, storage container for containing pesticide.It is a device which is specifically designed to spray both organic and inorganic liquid easily and quickly.

II. POWER OUTPUT VERSES TILT ANGLE

The Power output of a solar panel depends on tilt angle and the direction towards which solar panel faces. The solar panel should be tilted according to latitude of that location and it should be facing due south if the location is in northern hemisphere. Solar module should be installed so that as much radiation is collected as possible. Ideally the solar module should be tilted at an angle to the horizontal (β_0) as shown in the figure, faced towards south such that the angle between the sun and solar module should be 90^0. As the Bhubaneswar Latitude is 20^0N 85^0E.So the Solar Panel was tilted at 20^0 and as it is in Northern hemisphere it was facing towards south.

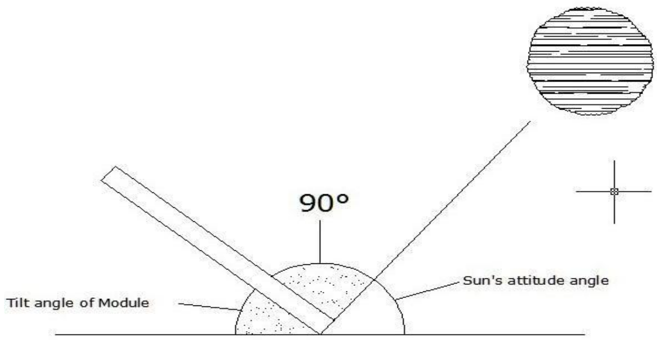

Figure A. Tilted angle of module

III. LITERATURE SURVEY

A.A Ghoneim et al [1] had done a simulation program to access the performance of PV water Pumping system. In this paper, the performance of the system was affected by variation of solar source. The performance of system depends on the variation of water head, but there is no significant change of performance due to variation of tilt angle. M. Benghanem et al [2] had done an experiment and had observed how the pumping head affected on efficiency of solar water pumping system. It was found that the efficiency of system increased with increasing solar radiation as well as at maximum power output of Pump. W.X.Shen et al [3] had done the optimization for sizing of solar array and battery in standalone Photovoltaic system in Malaysian weather condition and had calculated the loss of power supply probability of Solar Photovoltaic system. The solar cell temperature affects the output power of a solar array significantly. The relation between solar cell temperature (T_{Cell}) and ambient temperature ($T_{Ambient}$) was established and T_{Cell}= $T_{Ambient}$*(1+1.25*H), where H is the average solar radiation over a day in the units kW/ m2.Essam E. Zahab et al [4] developed a standalone PV water pumping system which consists of PV panel, lead acid battery, and a water pump driven by brush less DC motor. There

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were three main controller used named as speed controller, MPPT (maximum power point tracking System) and controller for charging and discharging of battery. Nithin Vasanth et al [5] developed a solar powered automatic sprayer which uses solar energy to charge battery. It consists of DC Pump and nozzle to spray the pesticide. The system had used GSM/Cellular Data which passes all the instruction to system. Accordingly four-wheeled vehicle was moved in a pre-fed path. Yallappa D et al [6] developed a solar powered sprayer which had discharge about 82.8 liters/hour and it can be used for multipurpose like charging the battery of mobile, used for domestic lightning purpose. M. Kohle [7] had done performance testing of a photovoltaic water pumping system. With the of help manual tracking and changing the solar intensity and solar cell temperature he had got 20% more output as compared to fixed tilted PV array. B. Poudel et al [8] designed semi automatic pesticide sprayer which was operated by wireless remote and micro controller and maximum discharge rate 0.556 liters/minute.

IV. DESIGN AND CALCULATIONS

Schematic diagram of solar sprayer

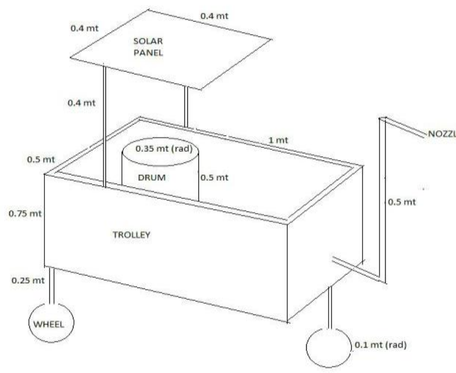

Figure B. Schematic diagram of Agro spraying system

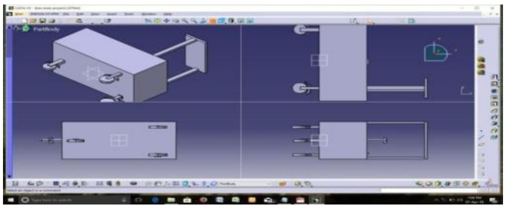

Figure C. Catia designed model

A. Sizing of DC Pump

Type: Photovoltaic powered DC motor coupled with Centrifugal Pump
Liquid Discharge, Q= 4 litre/minutes
Speed of the DC motor= 3600 RPM (Rotation per minute)
Power output = 12 Watt

B. Calculation of Shaft power of DC pump

Discharge of Liquid: 4 litres/ minute.
Suction Head (h_s) = 0.5m.
Discharge Head (h_d) = 3m.
Suction pipe Diameter (d_s): 8mm =8×10^-3m.
Discharge pipe Diameter (d_d): 8mm =8×10^-3m
Overall Efficiency of the Pump
$\eta = (W \times H_m)/(1000 \times S.P.)$
Where, S.P = Power Required To Drive The Pump.
H_m = Manometric Head (in meter)
η= Assuming Overall Efficiency of the Pump to be 80%
W=Weight of water to be lifted
$\eta = (\rho \times g \times Q \times H_m)/(1000 \times S.P)$
Where, Q= 4lit/min=0.004m^3/60sec=6.66×10^-5 m^3/sec.
H_m= Manometric Head.
$H_m = h_s + h_d + hf_s + hf_d + (V_d\text{^}2/2\times g) + P_a/(\rho \times g)$
Where,
h_s =suction head= 0.5m
h_d =delivery head= 3m
$P_a/(\rho \times g)$=Atmospheric Pressure head= 10^5/(1000×10)=10m/sec.
$Vo\text{^}2/(2\times g)$ = Velocity head of water in delivery pipe = $(V_d$ ^2)/(2×g)
hf_s = frictional loss in suction pipe=(4 × f× L_s × Vs^2))/(d_s × 2g)
hf_d = frictional loss in delivery pipe=(4 × f× Ld × V^2))/(d_d × 2g)
f=co-efficient of friction which is a function of Reynolds number
Re= (V× d)/ ν
Re=Reynolds number
ν =Kinematic viscosity
L_s = Length of suction pipe=1m
L_d = Length of discharge pipe=2m
V=mean velocity of flow
For suction pipe, Velocity at suction pipe=
$V_s=Q/A_s=Q/((\pi/4)\times d_s\text{^}2)$=6.66×10^-5/(π/4×(8×10^-3)^2)=1.32m/sec
Re = (V_s×d_s)/ ν = (1.32×8×10^-3)/.01×10^-4=10560
f=0.079/10560^ (1/4) =0.0077
$hf_s=(4\times f\times L_s\times V_s\text{^}2))/(d_s\times 2g)$= (4×0.0077×1×1.32^2)/2×9.8×8×10^-3)=0.34m
For discharge pipe,
$V_d=Q/A_d=Q/((\pi/4)\times d_d\text{^}2)$=6.66×10^-5/((π/4)×(8×10^-3)^2)=1.32m/sec
Re= (V_d×d_d)/ ν = (1.32×8×10^-3)/.01×10^-4=10560
f=0.079/Re^ (1/4) =0.079/10560^ (1/4) =0.0077
$hf_d=(4\times f\times L\times V_d\text{^}2))/(d\times 2g)$=(4×.0077×4×1.32^2)/2×9.8×8×10^-3)=1.36 m
$H_m = h_s + h_d + hf_d + hf_s + (V_d\text{^}2/2\times g) + Pa/(\rho \times g)$
=3+.5+1.36+0.34 + (1.32^2/ (2×9.8)) +10
=15.3m
$\eta = (\rho\times g\times Q\times H_m/(1000\times S.P.)$
$S.P=(\rho\times g\times Q\times H_m)/(1000\times\eta)$=(1000 ×9.81×6.66×10^-5×15.3)/(1000 × .4)
= 24.9×10^-3kw=24.9 watt
= 25 watt (approx.)

C. Sizing of PV panel, Battery and Charge controller

1. Sizing of Solar Panel

Load calculation=12 watt power output of DC Pump ×5 hour per day=60 Watt Hour
For climate condition total load =60+60=120 Watt Hour
Considering sunshine hour = 5 Hour
120 Watt Hour/5 ≈ 24 Watt
Hence 20 Watt Solar panel to be selected.

2. Sizing of Battery

For 3watt to 100 watt panel 12 volt is required.
120 Watt hour/12 volt=10 Ampere hour ≈ 7.2 Ampere hour

3. Sizing of Charge controller

24 Watt /12volt=2 Ampere hour ≈ 10 Ampere hour
Maximum current produced by Solar panel = Maximum power output/maximum voltage=20/12= 1.66 Ampere
Charging time of battery= Rating of battery in Ampere hour/maximum current produced
= 7.2/1.66= 4.34 Hours

D. Fabrication and operation sheet

Component: Frame & Plate
Material: - Stainless steel (202)

Serial No	*Description of the Operation*	*Types of Machine Used*	*Measuring Instrument*	*Time Period in minutes*
1	Cutting operation-Cutting of stainless steel beam	power hacksaw machine	measuring tape	30 minutes
2	Cutting operation-Cutting of stainless steel beam into pieces	power Hacksaw machine	measuring tape	30 minutes
3	Filling operation on cutting edge of beam	Bench vise & File	--------------	60 minutes
4	Welding the stainless steel beam to required size	Electric Arc Welding Machine (electrode:e308, electrodeholder)	Try square	120 minutes
5	Welding the stainless steel sheet to required size	Electric Arc Welding Machine (electrode: e308l,electrode holder)	Try square	120 minutes
6	Drilling the frame at certain point as per requirement	Drilling Machine	vernier caliper	10 minutes

E. Electrical connection

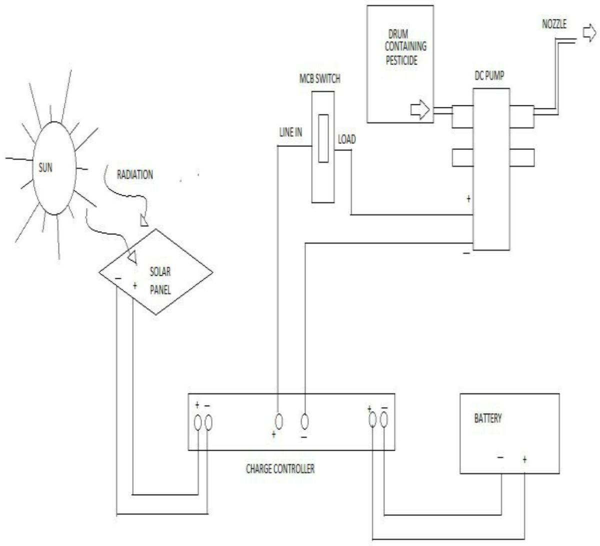

Figure D. Electric connection

The solar panel collects the radiation from sun and stores it in the dc current in the battery and charge the battery through control charger. When the charge in the battery is full and overloading the charge controller disconnects the connection from panel to the battery and simultaneously prevents battery from damage. Now the battery supplies the stored energy in it to the pump through MCB switch. One of the positive connections from charge controller goes to MCB switch and from the other end of switch the connection comes out and is inserted in the pump. Similarly one negative connection from charge controller goes to DC pump. When the MCB is switched on the current starts flowing through the wire and the pump starts to suck pesticides from tank and discharge it to nozzle.

Table-B. Specification of Solar operated sprayer

Sl.No	**Parameter**	**Specifications**
1	Solar panel	Maximum power 20W,V_{mp}=17 V,I_{mp}=1.18A
2	Battery	12 V,7.2 Ah
3	Charge controller	12V,10 A
4	MCB switch	61DC/10A,IP
5	Sprayer	Solar operated sprayer with nozzle
6	DC pump	12V,3.A,Discharge rate=4.2LPM,Press=5.8 Bar
7	Wheel	Castor
8	Tank	25 litre

IV. RESULTS

The water was filled in the drum and required amount of pesticide is added in it. The drum was tightened to avoid splashing of water in the trolley. The MCB switch was switched on to allow the motor to run in order to pump the pesticide. The pesticide was sprinkled in the required area as per the requirement. The unused pesticide was removed from the tank and the tank was cleaned.

Discharge of water at outlet of DC Pump

=Amount of water to be discharged/Time taken

= 2 liter /0.46

= 4.3 liters/minute

Discharge at outlet of Nozzle

=2/1.503

= 1.33 litre/minutes

Table C. Fluid Discharge Rate

sl. no	Time	Discharge at outlet of DC water pump (LPM)	Discharge at nozzle exit:(LPM)
1	7 AM	3.7	1.1
2	9 AM	4	1.3
3	11 AM	4.3	1.4
4	1 PM	4.31	1.42
5	3 PM	4.1	1.33
6	4 PM	3.9	1.15
7	5 PM	3.8	1.14

The variation in discharge rate of fluid through DC water pump exit and nozzle exit is due to minute variation of current and voltage due to variation of solar radiation at different phase of day.

A. *Calculation of efficiency of Solar Panel*

The solar cell efficiency will be calculated by taking the relation:

Ŋ=Pmax/Pin= output power/ input power Where, Pin = Solar Irradiance ×Area of Solar panel

Performance parameters are under Standard test conditions at irradiance of 1000 W/m² and cell temperature at 25^0C

Ŋ = output power / input power

Ŋ = 27.735 /254.4 = 10 %

This is the efficiency of the solar panel.

B. **Voltage and current variation of DC pump and solar panel**

Table D. with Battery and Charge controller

	DC Pump		Solar Panel	
Time	*Open Circuit Voltage (Volt)*	*Short Circuit current (Ampere)*	*Open Circuit Voltage (Volt)*	*Short Circuit current (Ampere)*
7AM	12.07	0.8	20.0	1.11
9AM	12.1	0.81	20.3	1.13
11 AM	12.19	0.84	20.6	1.16
1PM	12.2	0.85	20.7	1.17
3PM	12.17	0.83	20.5	1.15
4PM	12.15	0.82	20.4	1.14
5PM	12.02	0.79	20.1	1.12

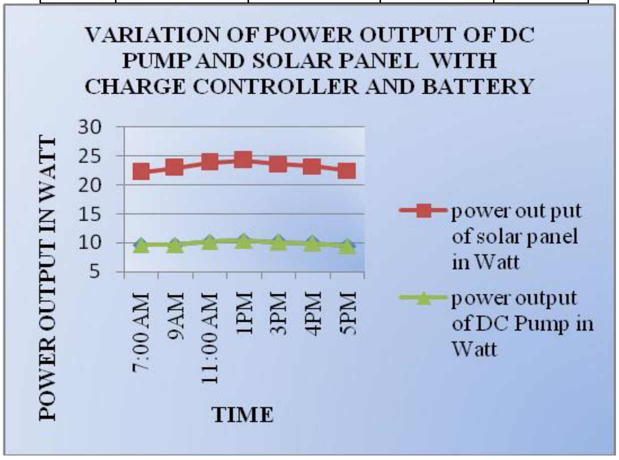

Figure E. shows variation of power output of DC Pump and solar panel with charge controller and battery

Table E. without Battery and Charge control

		DC Pump		Solar Panel	
Sl. no.	*Time*	*Open Circuit Voltage (Volt)*	*Short Circuit Current (Ampere)*	*Open Circuit Voltage (Volt)*	*Short Circuit Current (Ampere)*
1	7 AM	12.07	0.5	20.0	0.8
2	9AM	12.1	0.6	20.3	0.9
3	11 AM	12.19	0.77	20.6	1.09
4	1PM	12.2	0.85	20.7	1.17
5	3PM	12.17	0.75	20.5	1.02
6	4PM	12.15	0.71	20.4	0.95
7	5PM	12.02	0.4	20.1	0.84

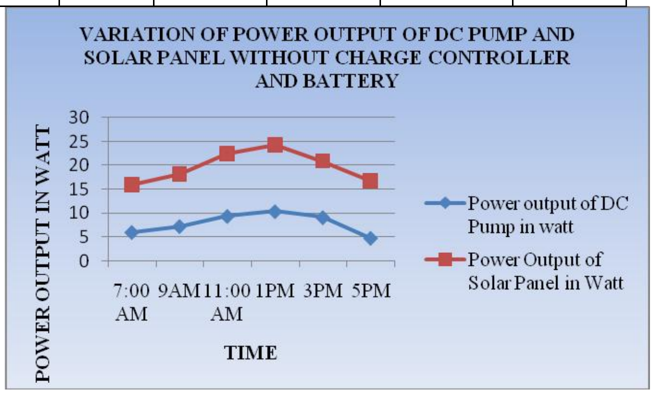

Figure F. shows variation of power output of DC Pump and solar panel without charge controller and battery

V. DISCUSSION

A. For finding power output of dc pump and Solar Panel, the open circuit voltage and short circuit current was calculated by taking the measuring instrument as Multimeter throughout the day with regular interval. It was observed that the maximum power out reached at 1 pm and also maximum discharge rate of liquid. For getting maximum power output, the Solar panel was tilted according to the latitude of the location. As the location was in Bhubaneswar, so the panel was tilted at 20^0 and towards south as the Bhubaneswar latitude ($20^0$10’25”N $85^0$42’26”E).

B. For getting maximum efficiency of the solar operated spraying machine, proper site survey was taken and solar panel was installed at shadow free location. It was observed that, there was considerable variation in the power loss due to partial shadowing of parallel row of cell.

C. The maximum discharge at outlet of DC Pump was found 4.31 Litres /minutes. From the observation it was found that there was a small variation of discharge rate. The efficiency of the DC Pump was calculated by $\eta=\rho g\ Q\ H_m$ /Open circuit voltage× Short circuit current where Q= Maximum discharge at outlet of DC Pump=4.3 liters per minutes/60×1000=7.15×10^{-5} m^3/sec.

D. From the figure it has been observed that there is a small variation of power output measured from DC Pump and Solar Panel by using Charge controller and Battery as compare to without use of charge controller and Battery.

E.$\eta=1000\times9.81\times7.15\times10^{-5}$ ×15.3/12.19×1.17=10.7457/14.2623=0.75×100=75%.So maximum efficiency of DC Pump was found 75%.

Efficiency of sprayer= maximum discharge at outlet of nozzle exit=1.42 liters per minutes/60×1000= 2.36×10^{-5} m^3/sec

$\eta = 1000\times9.81\times2.36\times10^{-5}\times15.3/12.19\times1.17=24.88\%$

Maximum efficiency of Sprayer was found 24.88%

Then Coefficient of performance of solar operated spraying machine was found= Efficiency of sprayer / Efficiency of DC Pump=24.88/75=0.33

As the battery and charge controller was connected, so it can be operated in night mode and also there was less sun shine hour.

F. From the figure E and figure F it had been observed that there was a slight variation of power output of DC pump and solar Panel with uses of charge controller and battery as comparison of without uses.

Figure G. Full assembly view and testing of solar operated sprayer

V. CONCLUSION

1. The method used here to build solar powered pesticide pumping system is cost effective comparatively to an electrically operated hydraulic pump.

2. As it consists of Battery and charge controller, so it can be utilized in night mode as well as during off sun shine hour.

3. The sprayer was also tested in field and was found successful to spray agricultural chemicals.

4. Further it can be used for charging the battery of Mobile phone and also for operation of 12 Volt Led light.

5. Further modification can be done by mounting Grass cutter on the front side of the frame. It can be automated by using microcontroller to regulate the movement of wheel and spraying process.

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