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Design and Analysis of Solar PV Water Pumping System

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Abstract: Most of the developed and developing countries economy is depended on agriculture. Due to variations in climate and by unsustainable land management practices in dry land environment makes the desertification. It causes the crop failures, loss of perennial plant cover, reduced woody biomass and scarcity of fuel wood etc. To overcome the desertification, it should be sustain the agriculture across the country. To enhance the agriculture sector, the utilizing of renewable energy sources came into account for irrigation and water pumping. Solar water pumping system minimizes the dependence of conventional based electricity; there is a huge scope to utilize PV pumping system for water supplies, irrigation and agriculture in rural areas. The initiation of the work is to create the awareness about the solar PV water pumping system and design analysis for irrigation at rural area based on the type of irrigation, land area and cost.

Keywords: Irrigation, pump, solar, latitude, longitude, asparagus

1. INTRODUCTION

A solar-powered water pump could be a pump running on the electricity that is generated by solar photovoltaic modules. The advantage of using solar energy to generate energy for agriculture by using water pump systems to increase the water requirements for livestock and irrigation that appear to correspond with the seasonal increase in incoming solar power. These PV systems can also help in considerable long-term cost savings and a smaller footprint of the environment compared to conventional power systems when perfectly designed. The volume of water being pumped at a given interval by a solar-powered system depends on the total amount of solar energy available during that time. The flow rate of the pumped water is dictated by both the intensity of the available solar energy and the size of the PV array used to transform solar energy into direct current (DC) electricity. The components in a solar-powered water pump system s are

- The PV array and its support structure,
- An electrical controller, and
- An electric-powered pump

The following information is required to design a PV-powered water pump:

- The site-specific solar energy available referred to as “solar isolation”.
- The volume of water required in a given period of time for livestock or irrigation purposes, as well as for storage. A storage volume equal to a three-day water requirement is normally recommended for livestock operations as a backup for the system’s safety features and cloudy days.
- The total dynamic head (TDH) for the pump water.
- The system’s proposed layout.

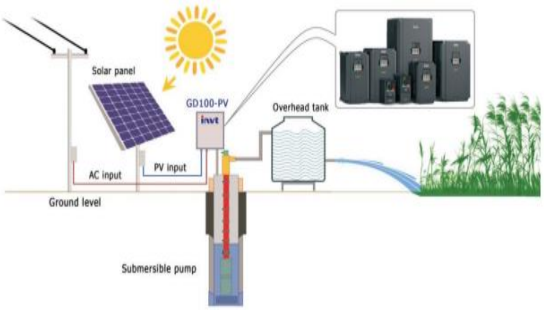

Fig. 1: Solar powered water pumping system

The following sections can provide an introduction to the basic concepts involved in solar-powered water pumping systems, design considerations for the previously mentioned, individual system components.

1.1 The major types of solar panels

Several types of solar panel are available in present market. Out of all the available, few are very useful and listed in below table 1.1.

Table 1.1 Types of solar panels

Solar panel types	Advantages	Disadvantages
Monocrystalline	High efficiency High performance Aesthetics	More Expensive when compare to other type of solar panels
Polycrystalline	Low cost	Low efficiency/performance
Thin-film	Portable and flexible Lightweight Aesthetics	Lowest efficiency/performance

1.2 Electricity Basics:

It is vital to be know about key electrical ideas, like power, energy, voltage, amperage, and opposition, before you start to plan a sun oriented fueled water siphon framework Voltage is the electrical potential for example the strain, in the sun based controlled framework. It is estimated in units of Volts (V). Ampere alludes to the development or stream of electrons (for example the electrical flow) through the framework. It is estimated in units of Amps (A). Voltage duplicated by ampere is the power delivered. It is estimated in units of watts (Wp), as displayed in

Watts = Volts x Amps

Electricity in a Wire	Water in a Pipe
Current (flow of electrons)	Discharge (flow rate of water)
Voltage (energy potential)	Pressure (energy potential)
Pressure (energy potential)	Hydraulic/Water Power = Q x Pressure
Resistance	Friction + Minor Losses
High Voltage, Small Wire= High Amps, High Resistive losses, Heat and Fires	High Pressure, small pipe=High velocity, High friction losses, Blowpipe

2. Types of Water Pumps in Agricultural System

Pumps are utilized broadly in farming to move water from the water source, which could be a stream, dam or bore, through lines to either a place of utilization or a storeroom, for example, a water tank or a water system framework.

There are two essential sorts of water pumps utilized in farming. The two kinds are intended to move water starting with one spot then onto the next constantly.

1. Centrifugal Water pump
2. Submersible Water pump.

2.1. Centrifugal Water pump

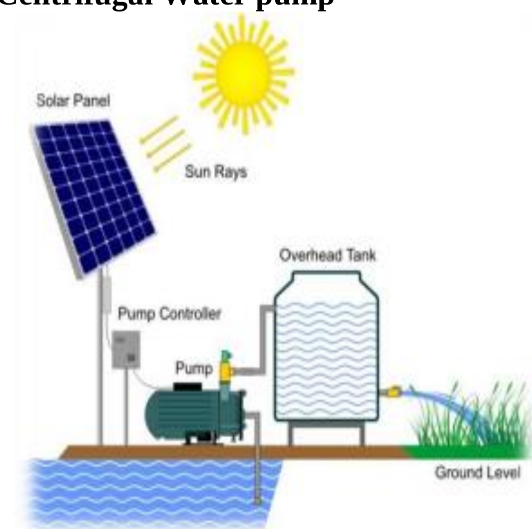

Fig 2: Centrifugal Water pump

Centrifugal water pumps are used extensively in agriculture to move water from the water source, which could be a river, through pipes to either a point of usage or a storage facility, such as a water tank or an irrigation system.

2.2. Submersible Water pump

Submersible water pumps are used extensively in agriculture to move water from the water source, which could be a dam, bore-well, through pipes to either a point of usage or a storage facility, such as a water tank or an irrigation system

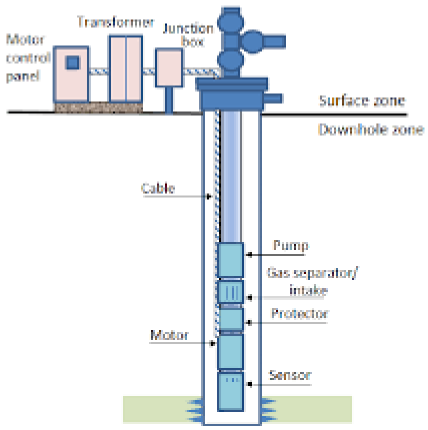

Fig 3: Submersible Water pump

2.2 PV Panel Orientation and Tracking:

To be handiest, PV panels have to be needed to incessantly and directly face incoming sunlight, they need the use of 1 or 2 tracking mechanisms. A single-axis tracking mechanism can rotate a PV panel to its vertical axis to follow the sun throughout the day. A double-axis mechanism will also manage the panel angle (the angle of the panel relative to horizontal wherever zero ° is horizontal and 90° is vertical) to regulate for the elevation of the sun within the sky throughout the year.

Single-axis t wrenching may be effective for increasing energy production throughout the year, by up to 50% throughout some months. Passive single trackers, that need no energy input, may be used. They use the heat from the sun to cause Freon or a substitute refrigerant to move between cylinders in the tracker assembly, which causes the panels to shift thus that they maintain a constant 90° angle to the sun throughout the day. Single-axis trackers tend to be additionally acceptable for sites between +/- 30°degress latitude. Also, their advantage at higher altitudes tends to be less throughout the winter months once the sun is low on the horizon.

3. CASE STUDIES:

Name of the field owner : Vutukuru Shiva
No. of acres : 4
Types of irrigation : Paddy & Cotton or any other
No. of yield in a year : 2 for every every 3 months and 1 for remaining time period
Location : Muchivolu village, venkatagiri, Nellore(dist),AP.

Solar PV water pumping system for depth of 26m in 4 acres land:

• Water Flow Rate/Discharge(Q)= Schem irrigation Need* 3600*hour/1000 (m^3/Day)
=703 /day (70,000 Liters/Day)

• Total Dynamic Head = Pumping level+ vertical lift+ Friction loss
TDH = 24.384+1.5+0.4876 =26.371

• Determine the solar radiation data=6 h/day
Note: Peak of 1000 W/m^3 equivalent, actually day length is longer

• Determine the hydraulic power of pump
$Ph = QpgTDH / 3600$
= 70∗1000*9.8∗26.3 / 3600
= **4954.4 W**
= **4.95KW**

• The induction motor power:
$Ph = pm / \eta m$ = 4.95 / 0.75 = **6.6 KW**

• Determine the energy required per day
The system is designed to run only during time (9 a.m. to 3 p.m.)
Total energy consumption per day = 6600*6
= **39,600 Wh/day**

• Determine the number of PV panels
Total watt power of PV = 39,600/4.32 = **9167 W**

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The total watt peak rating depends on the panel generation factor, which is different in each site location (India=4.32)

No. of solar PV panel required of 350 Wp each = Power rating of motor/350 = **21 panels**

- Determine the inverter rating = *pm* + *pm**0.25 = **7 KVA**
- Battery voltage **= 180V**
- Number of batteries requires = Actual Battery Voltage/Battery Voltage Range

  = 180/24 **= 8(series)**
- Battery charging capacity = Energy consumption per day/Battery voltage

  = 39,600/180 = **220 AH**
- Charge controller = Inverter size/Controller efficiency

  = 7/0.9 = **8 KVA**
- Total ampere required for PV panel = Battery Charge Capacity/hours

  = 220/6 =**36.6 A**

Panel design

- Panel connected modules = Total amperes required by PV module/Panel current

  = 36.66/8.75 **= 4 Modules** (Panel current = 8.75A)
- Series module = Battery voltage/panel voltage = 180/40 **= 5Modules**

  (panel voltage = 40v)

4) Procedure for Calculating The Solar PV Panels for Water Pumping System

Step-1: The total water flow rate per day
Q = Scheme Irrigation Need*3600*hour/1000 (m^3/Day)

Step-2: Total dynamic head (TDH)
TDH = Pumping level+ vertical lift+ Friction loss

Step-3: Hydraulic power required per day
Ph = $QpgTDH$ / 3600

Step-4: Solar radiation data in hours per day
Approximately 6 h/day

Step-5: Pump size

Step-6: Hydraulic power of pump

Step-7: No. of PV panels
= Total energy consumption per day /Panel generation factor

Step-8: Inverter rating
= *pm* + *pm**0.25

Step-9: Battery sizing
Take it as 180v

Step-10: Charge controller
= Inverter size/Controller efficiency

Step-11: Total Amperes required for PV panel
= Battery Charge Capacity/hours

Step-12: Panel Design
Parallel connected modules:
= Total amperes required by PV module/Panel current
Series modules =Battery voltage/panel voltage

5) Results for Proposed System

S.NO	Parameters	Theoretical	Practical
1	No. of Parallel Batteries in the Bank	8	8
2	Value Of Vertical Lift	1.6m	1.5m
3	TDH	26.37	26
4	Required Running hour Per Day	6 hour/day	6hour/day
5	Hydraulic power of pump	4.95KW	4.95KW
6	Induction motor power	6.6KW	6.6KW

7	Energy consumption /day	39,600 Wh/day	39,600 Wh/day
8	Power of PV panels	9167W	9167W
9	No. of PV panels	21	350
10	Inverter rating	7	7
11	Series Modules	5	5
12	Parallel Modules	4	4

6) COST ANALYSIS

The estimating of payback period can be done in 2 ways

1. Simple payback period
2. Life cycle cost[LCC]

Simple payback period:-

The time required for money recover is determined by dividing the initial investment in a PV system to the cost of energy savings due to PV system is called simple payback period.

Simple payback period=X/Y years

Where, X=Initial Investment Cost

Y=Annual cost of energy saving

The Central Government will give Central Financial Assistance(CFA) of 30% of the benchmark cost or 30% of the delicate expense

The State Government will likewise offer monetary help (30% of benchmark cost). In this way, the ranchers would be expected to pay just 40% of the expense of the independent solar siphon.

Anyway the rancher can profit bank monetary of up to 30% of the expense. Along these lines, at first, just 10% expense will be pay by the rancher.

The Central Government will give Central Financial Assistance (CFA) of 30% of cost=2,74,000*0.3=82,200 Rs

The State Government will likewise offer monetary help of 30% of cost= 2,74,000*0.3=82,200 Rs rancher can profit bank monetary of up to 30% of cost= 2,74,000*0.3=82,200 Rs rancher will pay just 10% of the expense=274000-82200-82200-82200 =27,400 Rs

6.1 PAYBACK PROFIT ANALYSIS

The former has yield in a year 2 for every 3 months (paddy) and 1 for remaining (cotton) and This is soil land. Because of soil land the water requirement is low. So in one day the motor has been used 4 hours.

- Motor consume electricity = **4*3.72 = 14.88 Units per day**
- Monthly consume from motor = **14.88*30 = 446.4 Units per month**
- The annual energy consume energy from the motor = **446.4*12**
  =5256.8 Units per year
- Annual cost of energy saving (Y) = **5256.8*2 = 10713.6 Rs**
- Payback period = X/Y years = **27000/10713.6 = 2.5 years**
- Payback profit (in paisa) = **Y/X = 10713.6/27000 = 39 paisa**

We consider the farmer can avail bank financial of up to 30% of the cost with zero percent interest and add with Starting investment from farmers **=82200+27000**
=1, 09,200 Rs

- Annual cost of energy saving (Y) = **5256.8*2 = 10713.6 Rs**
- Payback Profit (in paisa) = **10713.6/109200= 98Paisa**
- Annual payback profit = **98-39 = 59 paisa per unit**

7) BENEFITS FOR FARMERS

- Within few years we'll clear all the loans and we'll be in profit zone
- The uses with this system are It provides us 24 hours power for farming It makes us independent on other power supplies.
- It avoids the loss of human from unwanted and confusing wires at the farms.
- We can operate it through mobile from the home, So there is no need of human effort

- The main useful thing is when the on grid is established in the future, we can provide power supply to the grid so that we can gain income.
- There is also no maintenance cost since the company manages the maintenance cost and also they will give warranty to the equipment.
- In this system the panels used will have a life time up to 25 years with zero maintenance and no repairs If there is any need of maintenance or repair the manufacturer company will do this for free.
- We can provide power supply to the grid
- By this we can also reduce pollution.

CONCLUSION

In this study, farmers are enlightened towards solar PV water pumping system to sustain the agriculture. The case study highlighted the sizing and designing of Solar PV water pumping system in real competitive world with less installation cost and screening the farmers with the availability of the central Government scheme utilization to sustain the agriculture for better tomorrow. based on our study, the solar water pumping system which is very friendly and helpful system for us especially to the farmers. It is mainly useful to the farmers. Therefore we are doing this study to create the awareness among farmers about solar water pumping system. If we use Solar Tree, the land requirement will be reduced compared to the traditional PV system.

In future, if we install Separate agriculture feeder with solar water pumping system they will provide continuous power supply

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