

Utilization of Solar Energy for Driving a Water Pumping System

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Abstract - Renewable energy sources in general, and Solar Energy source in particular, has the potential to provide energy services with zero or almost zero emission. The solar energy is abundant and no other source in renewable energy is like solar energy. The solar-powered pumping system can be used anywhere but it is appropriate for rural areas which is facing energy crisis. Due to geographical position, sultanate of oman and gulf region has ample sunshine throughout the year which makes it ideal location for utilization of solar energy. Small farms, villages, and animal herds in developing countries require hydraulic output power of less than a kilowatt. Many of these potential users are too far from an electrical grid to economically tap that source of power, and engine-driven pumping tends to be prohibitively expensive as well as unreliable due to the high cost of purchased fuel and insufficient maintenance and repair capabilities.

A solar-powered pump is a normal pump with an electric motor. Electricity for the motor is generated on-site through a solar panel which converts solar energy to direct-current (DC) electricity. Because the nature of the electrical output from a solar panel is DC, a solar-powered pump requires a DC motor if it is to operate without additional electrical components. If a pump has an alternating-current (AC) motor, an inverter would be required to convert the DC electricity produced by the solar panels to AC electricity. Due to the increased complexity and cost, and the reduced efficiency of an AC system, most solar-powered pumps have DC motors. DC motor has been used to drive solar energy water pump system. This paper consists of frame of solar water pump, DC motor, pump, solar panel, suction pipe, delivery pipe, ON/OFF control switch and water tanks.

Key word: DC motor, solar energy, solar panel, pump

1. INTRODUCTION

Solar energy is radiant light and heat from the sun harnessed using a range of ever-evolving technologies

such as solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial photosynthesis. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air [1].

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise.

The Earth receives 174 peta watts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

2. PRINCIPLE OF OPERATION OF SOLAR ENERGY

Solar energy is available in abundance in most parts of the world. The amount of solar energy incident on the earth's surface is approximately 1.5×10^{18} kWh/year, which is about 10,000 times the current annual energy consumption of the entire world. The density of power radiated from the sun (referred to as solar energy constant) is 1.373 kW/m^2 .

Solar cell is a device which converts photons in Solar rays to direct-current (DC) and voltage. The associated technology is called Solar Photovoltaic (SPV). A typical silicon PV cell is a thin wafer consisting of a very thin layer of phosphorous-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact (the P-N junction).

When the sunlight hits the semiconductor surface, an electron springs up and is attracted towards the N-type semiconductor material. This will cause more negatives in the n-type and more positives in the P-type

semiconductors, generating a higher flow of electricity. This is known as Photovoltaic effect.

The amount of current generated by a PV cell depends on its efficiency, its size (surface area) and the intensity of sunlight striking the surface. For example, under peak sunlight conditions a typical commercial PV cell with a surface area of about 25 square inches will produce about 2 watts peak power.

What is a solar-powered pump?

A solar-powered pump is a normal pump with an electric motor. Electricity for the motor is generated on-site through a solar panel which converts solar energy to direct-current (DC) electricity. Because the nature of the electrical output from a solar panel is DC, a solar-powered pump requires a DC motor if it is to operate without additional electrical components. If a pump has an alternating-current (AC) motor, an inverter would be required to convert the DC electricity produced by the solar panels to AC electricity. Due to the increased complexity and cost, and the reduced efficiency of an AC system, most solar-powered pumps have DC motors[2].

Solar-powered pumps will naturally work best on sunny days, which is fortunate because cattle will consume more water on hot, sunny days. But, water is still required on cloudy days. Solar panels still produce some electricity when it is cloudy, but their output is diminished. To ensure that ample water is always available for livestock, solar-powered water pumping systems should incorporate storage sufficient to supply water requirements for three or four days.

The components comprising a solar-powered pump depend on whether the pumping system is a direct-drive system or a battery-operated system. In direct drive system, solar energy is observed by solar panel which convert solar energy into direct current which drive the DC motor pump through which water is transfer from water source to water storage. In case of battery operated system, solar energy is observed by solar panel which convert solar energy into direct current which is stored in the battery then current supply from battery to DC motor to drive pump through which water is transfer from water source to water storage.

Both systems should incorporate a water-storage facility, but the water-storage component of the battery-powered system can be reduced in size relative to the direct-drive system due to the fact that the batteries effectively provide some storage. In the research work, solar power pumping system is based up on Direct- Drive System [3].

For the direct-drive systems, it is important to match the power output of the solar array with the power requirements of the pump to maximize efficiency. For the battery-powered systems, it is important to use good-quality deep-cycle batteries and to incorporate electrical controls such as blocking diodes and charge regulators to

protect the batteries. Some solar panels incorporate the electrical control elements.

Solar-powered pumping systems can be configured to meet a wide variety of demands. The amount of water a solar powered pump can deliver is a function of how far the water has to be lifted, the distance it has to travel through a delivery pipe (and the size of pipe), the efficiency of the pump being used, and how much power is available to the system. Power can be increased by adding more solar panels [4].

One of the main advantages of a solar-powered pumping system is its simplicity and durability. The pump is the only part of the system having any moving parts, and it comprises a relatively small portion of the total system cost. Unless the system is installed in an extremely dusty area, occasional inspection of the wiring and the general appearance of the panels will be all that is necessary. Panels can be cleaned with plain water and a soft cloth. The frequency of inspection should match the amount of storage available. For example, if the system incorporates a three-day supply of water and/or energy in storage, then it should be inspected at least every three days [5].

Objective of this research paper is

- Replacement of Non Renewable energy resources to renewable energy resources.
- Utilization of solar energy.
- Production of electricity in remote area.

3. LITERATURE REVIEW

Within the last few years, a number of studies have provided upon solar powered pumping system. An insight of related studies is as follows:

Solar water pumps can provide simple and low labor watering options for farms that require water in remote areas. Several general points to keep in mind about solar water pumping include:

Water storage in metal or plastic tanks is used instead of power storage in a battery. This reduces costs and makes the system simpler. A float switch turns the pump off when the tank is full[6].

An electronic pump controller is used to smooth out the current to the pump. It acts like an automatic transmission in the sense that it helps the pump to start and to operate in low light conditions. As with the turtle and the hare, slow and steady wins the race. Many solar pumps are made to pump slowly over the course of the day, which allows water to be pushed over considerable distances and vertical rises. Slow pumps can use small diameter piping, reducing the installed cost. Slow pumps require less power and allow the use of limited water resources, such as a slowly recharged well. To reduce the cost of a system, water conservation must be practiced. PV modules are expensive, and reducing water use in any manner will save on the installed cost. Solar pumps are generally most competitive in smaller systems where combustion engines are least economical. Solar pump

systems are low maintenance. With automatic shut off from a float valve, they require only occasional inspection [7].

The output of a solar pumping system is very dependent on good system design derived from accurate site and demand data. It is therefore essential that accurate assumptions are made regarding water demand/pattern of use and water availability including well yield and expected drawdown.

With a solar pump, energy is not available on demand, and the daily variation in solar power generation necessitates the storage of a surplus of water pumped on sunny days for use on cloudy days, solar energy needs to be reserved in the form of either electricity in batteries or lifted water in a storage tank. The suitability of solar power for lifting water to irrigate plants is undeniable because of the complementary between solar irradiance and water requirements of crops. The more intensively the sun is shining the higher is the power to supply irrigation water while on the other hand on rainy days irrigation is neither possible nor needed[8].

Water pumping has long been the most reliable and economic application of solar-electric (photovoltaic, or PV) systems. Most PV systems rely on battery storage for powering lights and other appliances at night or when the sun is not shining. Most PV pumping systems do not use batteries – the PV modules power the pump directly[9].

Based upon literature review we have fabricated solar energy driving water pump system.

4. PROCESS INVOLVED

4.1 Making Water Tank

Two piece of blank of G.I. sheet have been cut from G.I. sheet having length 1000 mm and width 1000 mm by using shear cutting machine. Bending operation has done on bending machine and making required shape and size on hydraulic press. Welding operation has done by using oxy-acetylene gas welding machine with the help of filler material. A source tank and discharge tank has been made of size 400 mm x 400 mm x 300 mm.

4.2 Frame of Solar Water Pump

Frame of solar water pump has been made by using mild steel square pipe and angle bar of different size.

Frame of solar water pump has been made by joining all mild steel square pipe and angle bar with the help of arc welding machine .G.I. sheet has been fixed on the table using rivets by riveting machine.

4.3 Pump with Shaft Coupling

Shaft coupling has been made from mild steel of length 105 mm having different in diameter of 25 mm, 15 mm and 11 mm using lathe machine. A hole of diameter 4 mm has been made by drilling machine

Pump has been used for pumping water. A shaft coupling is used for fixing impeller on one end of shaft then placed

in the pump. The other end of shaft is connected to DC motor shaft with the help of taping screw.

4.4 D C Motor

A D C motor of model – MY1016, voltage- 24v, speed – 2500 rpm, current – 14 Amp and output – 250 watt has been used for driving water pump. It has been purchased from market. An electric motor is a machine which converts electrical energy to mechanical energy. Its action is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a magnetic force whose direction is given by Fleming's left hand rule. When a motor is in operation, it develops torque. This torque can produce mechanical rotation.

4.5 Solar Panel

A solar panel is a packaged, connected assembly of photovoltaic cells. Solar panel is rated by its DC output power. It has crystalline silicon cell and 8 A/21.6 V; 150 watt. It has a size of 1480 mm x 660 mm. The efficiency of a panel is determined by the area of a panel. Solar panels use light energy from the sun to generate electricity through the photovoltaic effect. Electrical connections are made in series to achieve a desired output voltage.

4.6 Pipe and Elbow

A mild steel pipe of diameter 1/2" has been used as a suction pipe and PVC hose pipe of diameter 1/4" has been used as delivery pipe. An elbow of diameter 1/2" has been used for connecting two mild steel suction pipes. A delivery pipe of small diameter has been used to increase the pressure inside pump.

4.7 Motor pump fixture

A motor pump fixture of G.I. sheet has been made for fixing motor pump assembly system on table. It has been fixed on the table with the help of nut and bolt. It has been used for arresting vibration during running motor pump.

4.8 Assembly of Solar Water Pump System

A different part of solar water pump system has been made and then assembled together. An assembly of solar water pump system is shown in figure 1.



Fig.1.Assembly of solar water pump system
4.9 Bill of Materials

A 2D drawing of complete assembly of solar water pump system using AUTOCAD 2013 is as shown in figure 2. Bill of materials for solar water pump system is given in table - 1.

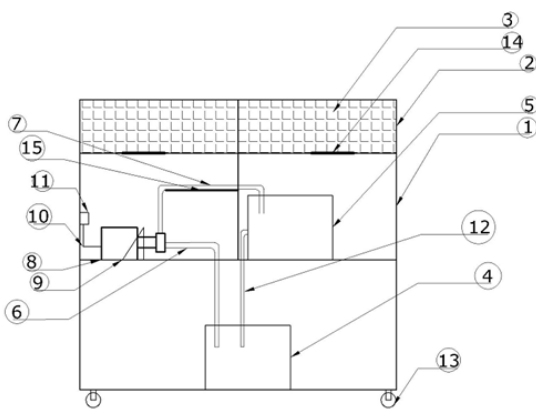


Fig.2 Drawing of solar water pump system

15	Delivery Pipe Support Frame	1	M5 Flat 20 mm x 3 mm
14	Solar Panel Frame Hinge	2	Mild Steel
13	Roller Wheel	4	Medium Duty; Plastic
12	Overflow Pipe	1	1/4" Plastic Hose
11	ON/OFF Control Switch	1	13A/250V; 405 watt
10	Power Chord	1	H05 VV-F; 2.5 x 3C; 300 - 500 V
9	Motor Fixture	1	G.I.Sheet - 250 mm x 140 mm x 100 mm; Sheet Thickness - 2 mm
8	Motor - Pump Unit	1	Model - MY1016; 14A/ 24V/DC; 2500 RPM; Output - 250 watt
7	Delivery Pipe	1	1/4" Plastic Hose
6	Suction Pipe	1	Mild Steel - 1/2" Diameter
5	Source Tank	1	G.I.Sheet - 400 mm x 400 mm x 300 mm; Sheet Thickness - 2 mm
4	Discharge Tank	1	G.I.Sheet - 400 mm x 400 mm x 300 mm; Sheet Thickness - 2 mm
3	Solar Panel	1	Silicon; 8A/21.6 V; 150 watt
2	Solar Panel Frame	1	M5 Angle - 1490 mm x 670 mm x 3 mm
1	Frame	1	Mild Steel - 1490 mm x 720 mm x 1360 mm
S.No.	Item	Quantity	Material

Table -1 Bill of Materials

4.10 Testing of Solar Water Pump System

A test has been conducted after assembly of solar water pump system. Performance of system has been achieved to our expectation level. Solar panel is connected to the motor pump through power chord for testing solar water pump system. A ON/OFF control switch is placed between solar panel and motor pump for starting and stopping the motor pump. All connection from solar panel to motor pump are connected in series. We place the solar system in sun light after some time when switched on motor started to drive pump and pump started driving water from source tank and deliver to discharge tank. Here light energy is converted in to electrical energy and electrical energy which drive the motor pump is converted into mechanical energy which deliver the water from source tank to delivery tank.

5. ADVANTAGES

- This system has the added advantage of storing water for use when the sun is not shining, eliminating the need for battery, simplicity and reducing overall system costs.
- It is an abundant Renewable Energy.
- It is a Non-polluting technology, which means that it does not release greenhouse gases.

- It is a Noiseless technology as there are few moving parts involved in energy generation.
- This technology requires Low-maintenance because of lack of moving parts.
- It can be installed on modular basis and expanded over a period of time.
- Most viable alternative for providing electricity in remote rural areas as it can be installed where the energy demand is high and can be expanded on modular basis.

6. LIMITATIONS

- As the technology is in an evolving stage, the efficiency levels of conversion from light to electricity is in the range of 10 to 17%, depending on the technology used.
- The initial investment cost of this technology is high.
- Solar energy is available only during daytime. Most load profiles indicate peak load in the evening/night time. This necessitates expensive storage devices like battery, which need to be replaced every 3 to 5 years. Generally, the cost of the Battery is 30 to 40% of the system cost.
- As the efficiency levels are low, the space required is relatively high. For instance, with the existing levels of technologies, the land required for putting up a 1 MW solar PV power plant is between 6 to 9 acres. However, research is going on to increase the efficiency levels of the cell.
- Solar energy is heavily dependent on atmospheric conditions.

7. APPLICATIONS

- Drinking water supply
- Village water supply
- Livestock watering
- Irrigation
- Process industry

8. CONCLUSION

Under the circumstances of inadequate supply of electrical energy, the solar water pump can play a significant role. Solar photovoltaic pumping offers an alternate means to meet the electricity demand for irrigation and livestock watering. The proposed solar water pumping system has long lifetime and it is maintenance free. Together with decreasing PV module costs and increasing efficiency, PV is getting more pervasive than ever[10].

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.

Sultanate of Oman is blessed with sun light throughout the year due to its global position. Therefore solar water pumping system has great prospect of utilization in this country.

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BIOGRAPHIES



Balkeshwar Singh has more 19 years of experience including industrial and teaching experience. He has worked at various positions in different engineering college of south and north India. He has also worked in North East Africa. Presently, he is working in Sultanate of Oman.



Anil Kumar Mishra has more than 25 years of experience. He has worked as a senior scientific officer II, IIT Delhi, project associate officer in NGO and different position in different engineering college of North India. Presently he is working as a professor in BA College of Engineering & Technology Jamshedpur, India.