Development of Solar Powered Water Pumping System

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Abstract

Providing clean, environmentally safe water for livestock in sufficient quantities continues to be a major concern for farmers and ranchers. Abundant water in remote locations in needed to insure that grasslands are grazed evenly. A solar powered water pumping system designed for remote locations was operated to determine the performance and reliability of the system and components. The system began pumping water when the solar radiation intensity exceeded. Flow increased linearly with radiation intensity and reached a maximum flow of intensity. Maximum flow was dependent on using the correct controller adjustment as well as the radiation intensity. Solar water pumping system operates on direct current. The output of solar power system varies throughout the day and with changes in weather conditions. Photovoltaic module, the power source for solar pumping, have no moving parts, requires no maintenance and last for decades. A properly designed solar pumping system will be efficient, simple and reliable. Solar powered pumping systems are used principally for three applications town and city water supply, livestock watering and irrigation.

Keywords: Solar Energy, Reciprocating Water Pump, Direct Current, DC Motor with Gear Box

I. INTRODUCTION

A. Introduction to Non-Conventional Energy Sources:

While fossil fuels will be the main fuels for thermal power, there is a fear that they will get exhausted eventually in the next century. Therefore other system based on non-conventional and renewable sources are being tried by many countries. These are solar, wind, geo-thermal, sea and bio-mass.

1) *Solar Energy:*

Solar energy can be major source of power. Its potential is 178 billion MW which is about 20000 times the world's demand but so far it could not developed on large scale. Sun's energy can be utilized as thermal and photovoltaic. The former is currently being used for steam and hot water production.

2) *Wind Energy:*

Wind energy which is indirect source of solar energy conversion can be utilized to run wind mill which in turn drives a generator to produce electricity. Wind can also be used to provide mechanical power such as for water pumping. The energy available in winds over the earth's surface is estimated to be 1.6X107 which is of same order of magnitude as present energy consumption on the earth.

3) *Geothermal Energy:*

Geothermal energy drives the heat in the Centre of the earth. According to various theories the earth has a molten core. The facts that volcanic action takes place in many places on the surface of the earth, supports these theories. The steam and hot water comes naturally to the surface of the earth in some location of the earth. India does not appear to have any major exploitable sources.

4) *Ocean Energy:*

Energy from seas can be utilized as wave tidal or ocean thermal energy. About 13 kW per meter height of wave can be generated. A plant to make 445000 kWh/yr of energy is being set up in Kerala State. Ocean thermal energy conversion utilizes the temperature difference between warm surface water at about 28°C and the cold deep sea water at 5-7°C at depth of 800-1000 meter in tropical areas. In India the Gulf of Kutch, Gulf of Cambay and Sunder bans are potential sites.

5) *Biomass Energy:*

Biomass is another renewable source of energy in the form of wood, agriculture residues, etc. The potential for application of biomass as an alternate source of energy in India is very great. We have plenty of agriculture and forest for production of biomass. Biomass is produced in nature through photosynthesis achieved by solar energy conversion. Biomass can be burnt directly to generate steam for use in steam turbine for power generation or they can be gasified and the gas used in an IC Engine.

B. Introduction to Solar Energy:

Sun is primary source of energy, and all form of energy on the earth is derived from it. Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be use, it will be one of the most important supplies of energy especially when other source in country have depleted.

Energy comes to the earth from the sun. This energy keeps the temperature of the earth above that in colder spaces, causes current in the atmosphere and in ocean, causes the water cycle and generates photosynthesis in plants.

The solar power where sun hits atmosphere is ^{1017} watts, whereas the solar power on earth's surface is $^{1016.}$ The total worldwide power demand of all needs of civilization is ^{1013} watts. Therefore, the sun gives us 1000 times more power than we need. If we can use *5%* of this energy, it will be 50 times what the world requires. The energy radiated by the sun in bright sunny day is approximately I kW/m^2.

Utilization of solar energy is of great importance to India since it lies in a temperature climate of the region of the world's where sun light is abundant for major parts of the year. India has the total land area of $3.28x10^{11}$ m^2. On an average *5* kW/m^2 per day solar energy is falling on this land over 300 days per annum.

C. The Application of Solar Energy:

- Heating and cooling of residential building.
- Solar water heating.
- Solar drying of agricultural and animal products.
- Solar distillation on a small community scale.
- Salt production by evaporation of sea water or inland brines.
- Solar cookers.
- Solar engines for water pumping.
- Food refrigeration.
- Bio conversion and wind energy, which are indirect source of solar energy.
- Solar furnaces.
- Solar electric power generation by solar ponds, steam generator.
- Solar photovoltaic cells.

II. LITERATURE REVIEW

A. Malawi Solar Powered Water Pump System BY:- Hunter King1 and Dr. Andre Butler2:

- ABSTRACT:

This project will consist of a water pumping system to supply potable water to an orphanage located in the Chuluchosema community of Malawi, Africa. The water will be pumped from a nearby well up to a water tower located in the orphanage center. The pump will be powered by a solar panel that will capture the solar energy from the sun. This project is in association with Mercer's University's Master's Program for Environmental Engineering and Mercer on a Mission. The water pump system will be built on Mercer's campus and will then be sent to the orphanage in Malawi to be assembled permanently. The water pumping system will be built by materials that are sustainable enough to allow the system to function properly long after the student has installed the system and has left. The intent of this project is to provide a hands-on experience for the graduate student by working with various professors and manufacturers as well as different contacts from the developing country. The goal of this project is to supply potable water to an orphanage without the residents retrieving it from a well.Keywords: Malawi Solar Water Pump.

B. Keywords: Solar water pumping; Pump; Photovoltaics; Efficiency; Diaphragm pump; Helical pump BY:- Brian D Vick , R.Nolan Clarck:

- ABSTRACT:

For several years, many types of solar powered water pumping systems were evaluated, and in this paper, diaphragm and helical solar photovoltaic (PV) powered water pumping systems are discussed. Data were collected on diaphragm and helical pumps

which were powered by different solar PV arrays at multiple pumping depths to determine the pumping performance, efficiency, and reliability of the different systems. The highest diaphragm pump hydraulic efficiency measured was 48%, and the highest helical pump hydraulic efficiency measured was 60%. The peak total system efficiency (e.g. solar radiation to pumped water) measured for the diaphragmand helical pumps were5% and7%, respectively (based on PV modules with 12% efficiency). The daily water volume of the three-chamber high head diaphragm pump performed better than the dual-chamber high head diaphragm pump (5 to 100% depend-ing on PV array input power and pumping depth). Use of a controller was shown to improve the quad diaphragm pump performancebelow a solar irradiance of 600 W/m2(20 m head) to 800 W/m2(30 m head). While diaphragm pumps made mostly of plastic demonstrated similar to much etter pumping performance than diaphragm pumps made with a high proportion of metal, the metal pumps demonstrated a longer service life (>2 years) than the plastic pumps service life (<2 years). Helical pumps analyzed in this paper were capable of deeper pumping depths and usually demonstrated a longer service life than the diaphragm pumps that were analyzed.Published by Elsevier Ltd.

C. Experimental Study Of Solar Water Pump BY:- Master of Science Erin Williamson:

- ABSTRACT:

Bio resource Engineering Solar water pump studies for small-scale rigation Irrigation is a well established procedure on many farms in western Canada and is practiced on various levels around the world. It allows diversification of crops, while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel. The overall objective of this research was to determine the feasibility of using photovoltaic (PV) modules to power a water pump for a small-scale drip irrigation system in Montréal (Québec, Canada). The study involved field observations, as well as computer simulations of global solar radiation and PV electrical output. Field observations involved a summer and winter installation of two amorphous silicon 42 W PV modules, directly connected to a 12 V surface water pump. The parameters monitored were voltage, current, back-of-panel temperature, pressure, and flow. These observed parameters were used to determine PV electrical output and volume of water pumped. Site latitude, elevation, and panel tilt were applied to the solar radiation and PV electrical output models, along with the following meteorological data: daily average, maximum, and minimum temperatures, and global solar radiation. Daily solar radiation prediction showed a linear correlation of 0.69 with the observed daily values, over the years 2000 to 2005. The correlation coefficient was improved to 0.91, when 7 day moving averages of both the observed and predicted solar radiation data were used. PV electrical output and volume of water pumped were monitored between August 2005 and May 2006. Both the power and water output observations were less than expected. However, the predicted daily PV electrical output ranged from 1.0 MJ d-1 in the summer to approximately 0.6 MJ d-1 in the winter. As expected, an increase in power caused an increase in the volume of water pumped.

III. METHODOLOGY

A solar powered water pumping system is made up of two main components,

1) Solar panels:
   - Photovoltaic module
2) Pumps:
   - Centrifugal
   - Reciprocating pump

There are two basic types of solar powered water pumping systems,

1) Battery based
2) Solar direct
   - A variety of factors must be considered in determining the optimum system for a particular application.
   - Battery based water pumping system consists of photovoltaic(PV) panels charge controller, batteries, pump controller and DC water pump,
1) Water supply for home or cabin.
2) Pumping at night

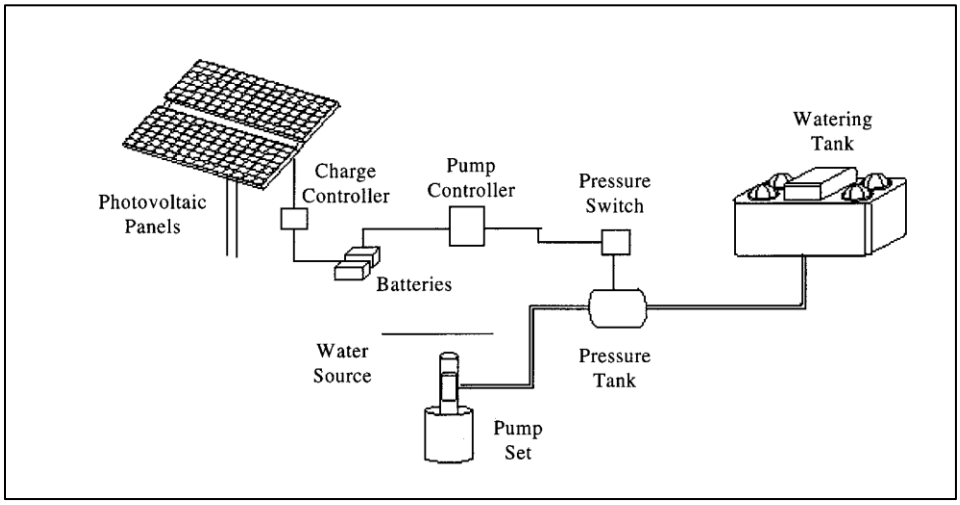


Fig. 1: Battery Based Water Pumping System

Reciprocating pumps are those which cause the fluid to move using one or more oscillating pistons, plungers or membranes (diaphragms).To 'Reciprocate' means 'To Move Backwards and Forwards'.

A 'RECIPROCATING' pump therefore, is one with a forward and backward operating action. The simplest reciprocating pump is the 'Bicycle Pump', which everyone at some time or other will have used to re-inflate their bike tyres. Reciprocating-type pumps require a system of suction and discharge valves to ensure that the fluid moves in a positive direction. Pumps in this category range from having "simplex" one cylinder, to in some cases "quad" four cylinders or more. Most reciprocating-type pumps are "duplex" (two) or "triplex" (three) cylinder. Furthermore, they can be either "single acting" independent suction and discharge strokes or "double acting" suction and discharge in both directions. The pumps can be powered by air,
Steam or through a belt drive from an engine or motor. This type of pump was used extensively in the early days of steam propulsion (19th century) as boiler feed water pumps. Reciprocating pumps are now typically used for pumping highly viscous fluids including
Concrete and heavy oils, and special applications demanding low flow rates against high Resistance.

A. Working Principle:

Reciprocating pump is a positive displacement pump, which causes a fluid to move by trapping a Fixed amount of it then displacing that trapped volume into the discharge pipe. The fluid enters a Pumping chamber via an inlet valve and is pushed out via outlet valve by the action of the piston or diaphragm. They are either single acting; independent suction and discharge strokes or Double acting; suction and discharge in both directions.

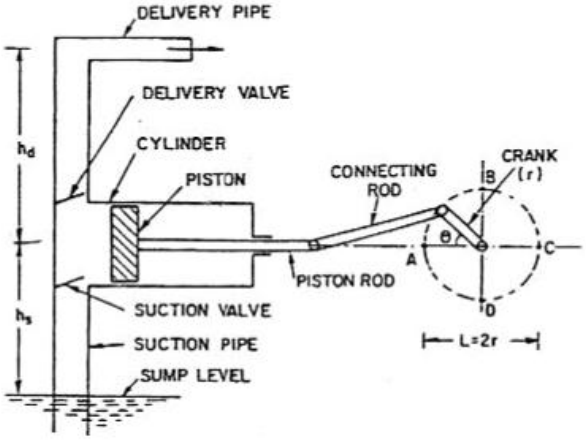


Fig. 2: Reciprocating Pump

During the suction stroke the piston moves left thus creating vacuum in the Cylinder. This vacuum causes the suction valve to open and water enters the Cylinder. During the delivery stroke the piston moves towards right. This increasing pressure in the cylinder causes the suction valve to close and delivery to open and water is forced in the delivery pipe. The air vessel is used to get uniform discharge.

Reciprocating pumps are self-priming and are suitable for very high heads at low flows. They deliver reliable discharge flows and is often used for metering duties because of constancy of flow rate. The flow rate is changed only by adjusting the rpm of the driver.

These pumps deliver a highly pulsed flow. If a smooth flow is required then the discharge flow system has to include additional features such as accumulators. An automatic relief valve set at a safe pressure is used on the discharge side of all positive displacement pumps.

The performance of a pump is characterized by its net head h, which is defined as the change in Bernoulli head between the suction side and the delivery side of the pump. H is expressed in equivalent column height of water.

IV. PARTS

- 24 WATT SOLAR PANNEL
- 24 VOLT BATTERY
- 12 VOLT MOTOR WITH SPEED REDUCTION GEARBOX
- CIRCULAR DISC
- CONNECTING ROD
- PISTON CYLINDER
- 2 NRVs
- SUPPLY PIPES
- SUMP AND OVERHEAD TANK
- BASE FOR SUPPORTING THE SYSTEM

V. OPERATIONS

A. Procurement of Material:

1) Pneumatic pump: - Instead of hydraulic pump over here pneumatic pump is used to reduce the cost of pump. The dimensions of the pump are 50mm * 150mm. At one end silencer is provided and by providing a branch tee at another end suction and discharge is provided. Forward motion of the piston is used for discharge and backward is used for the suction of water from the sump.
2) Dc Motor with speed reduction gear box: -12volt dc motor with torque magnification gear box is used to provide high starting torque to the disk and speed is reduced.
3) 20 Watt Solar panel: - A 20 watt solar panel is used to convert the incident solar energy into electricity of required amount.
4) Two 12v battery: - Two 12 battery is connected in series to obtain 24volt output.
5) Pipe: - Flexible pipe of 9mm * 12mm is used for suction from sump and delivery to the overhead tank.

B. Calculation and Development of Component:

L= LENGTH OF STROKE
R= RADIUS OF THE DISC.
L=2R
L=150mm, thus radius is L/2= 75mm.
Thus diameter of the disc is 150mm.

1) Disc: - The circular disk of 147mm diameter and 3mm thickness is used to convert rotary motion of the gear box to reciprocating motion for piston and cylinder.
2) Connecting rod: - A connecting of 264mm is used to connect the disk and the piston with a special attachment to provide reciprocating motion. The center hole distance is 233mm.

C. Fabrication Process:

1) *Cutting:*

25mm * 50mm MS pipe is used for construction of base .The base required for the structure is made from the rectangular pipe of length of 764.5mm and width of 276.8mm. Height of the base 124.5 mm. the base is build up by the cutting operation performed on the pipe for the required measurement. Connecting rod is made from the 25mm MS strip.

Fig. 1: Cutting Process

D. Drilling:

Hole of 15mm is drilled into the base pipe for holding pneumatic cylinder rigidly with the nut and bolt. Hole at both end of the connecting rod id drilled to connect with the disk and piston of the pump. A 10mm hole is drilled into the hub for attaching it with the shaft of gear box and two 5mm holed are radially drilled on the hub at 60 degree for holding the shaft and disc tightly.

Fig. 2: Drilling Process

E. Welding:

The base is build up by the joining pipe with the help welding. Also the stand for the structure is made by it. The hub is connected with disk by welding also the motor is joined rigidly with the base for smooth working with the help of the welding.

Fig. 3: Welding Process

F. Grinding:

Burrs and uneven surface developed because of welding process is finished by the grinding process.

Fig. 4: Grinding Process

G. Assembly:

First of all pneumatic pump is fitted to the base with the help of nuts and bolt, visor are used over here for the rigid fitting and to avoid vibration and miss alignment.

Fig. 5: Fitting Pump on Base

Then after one end of the connecting rod is attached to the disk with help of the bearing nut for the smooth rotational motion of the disk and the rod

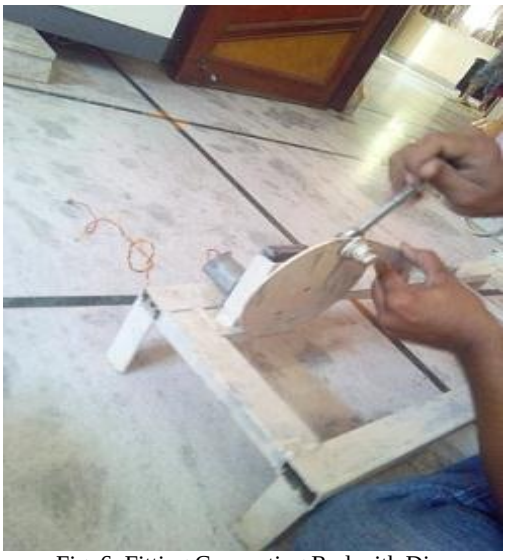


Fig. 6: Fitting Connecting Rod with Disc

Other end of the connecting rod is fitted to the piston rod of the pump by bringing the disk at TDC position and the piston rod completely inside the cylinder.

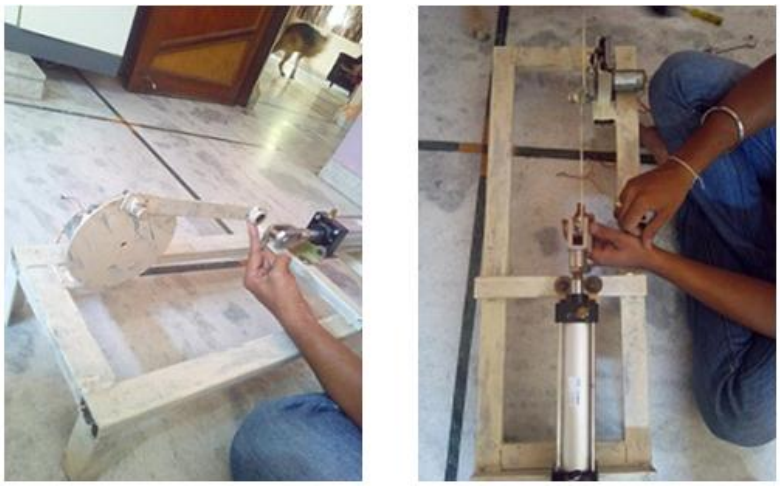


Fig. 7: Attaching Connecting Rod with Piston

A branch tee is connected to the pump from which the suction and delivery pipe are provided along with the nerves at both end.

Fig. 8: Attaching Tee with Pump

The delivery and suction pipe are adjusted in the sump and the overhead tank. Then after the motor is connected to the 24vol battery connected in series and the battery is simultaneously charged with the help of the 20watt solar panel.

VI. RESULT ANALYSIS

A. Theoretical Calculations:

Losses Ignored
Bore Diameter= 50mm
Length of stroke= 150mm
Head or height h=3.5m
Speed of rotation N=15rpm
Pipe Dia= 9mm
Pipe Length=1m
Suction lift= 0.5m

$$Q = \frac{\pi \times d^2 \times L \times N}{4 \times 60} = \frac{\pi \times (0.05)^2 \times 0.15 \times 15}{4 \times 60} = 7.35 \times 10^{-5}\ m^3/s$$

$$P = \rho \times g \times h = 1000 \times 9.81 \times 3.5 = 2.5 Watt$$

$$\text{Max speed (piston)} = \omega \times r = \frac{2 \times \pi \times N \times r}{60} = 0.07 m/s$$

$$\text{Max velocity of water in delivery pipe} = \frac{0.07 \times 0.05^2}{0.009^2}$$

= 2.16m/s

Head loss friction = $\frac{2\times\rho\times L\times V^2}{g\times D}$

Supply Inertia head = $\frac{L\times d_p^2\times\omega^2\times r}{g\times d_d^2}$

$= \frac{3.5\times.05^2\times1.4^2\times.05}{9.8\times0.009}$

= 1.05m

Suction Inertia head = -0.26m

B. Practical Calculation:

According to observations the Disc is rotating from TDC to BDC in 3secs that means one complete rotation will be occurring in 6 sec.

So the number of rotation per minute will be 10. As the disc will complete one rotation, one stroke of the piston will be completed. It has been observed that approx. one liter of water is delivered to the required head at the end of fourth stroke. That means the discharge is equal to 2.5 liters per minute.

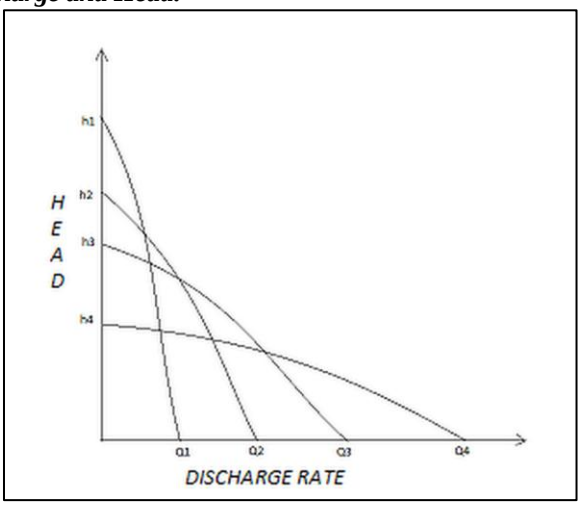
RPM= 10

Discharge in one stroke= 0.25 liter per minute

No of rotation = No of stroke

So, Total Discharge 0.25×10 = 2.5 liter/minute

C. Graph of Relation between Discharge and Head:



Graph 1: Discharge vs Head

VII. ADVANTAGES AND DISADVANTAGE

A. Advantages:

- Solar-powered Water Systems are practical in flat terrain where the sun shines.
- Solar-powered water pumps can be placed in or next to the pond or other source of water and the water can be pumped where it is needed.
- Solar water pumping is clean and efficient.
- Solar electric water pumping cuts down on waste because it's based on natural cycles. Your panels give the most pumping power on the sunniest days---when you need the most water.
- Solar power is clean. You never have to worry about polluting the groundwater or air with a gas-powered pump.
- Solar-powered water systems take very little maintenance because they only have a few moving parts. They have long life---usually 20 to 40 years. And solar water systems never run out of fuel as long as the sun is shining.

B. Disadvantages:

- Relatively high initial cost
- Lower output in cloudy weather

VIII. CONCLUSION

The method used here to build solar powered water pumping system is cost effective comparatively to an electrically operated hydraulic pump. Since here non-conventional energy is used to achieve the required head.

Discharge obtained from the observations is 2.5liters per minute. The reciprocating pump built by us is built with the help of simple and easily available materials still we have successful to demonstrate the worth of a reciprocating pump. This device serves its purpose to some extent, but with proper course of actions, it can perform still better.

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