Construction & Analysis of solar powered water pumping system for small scale application

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***Abstract*—In locations where electricity is less or unavailable, other channels are necessary to pump water for utilization. One alternative is a photovoltaic (PV) pumping system. Merits of PV pumping systems comprise low operating cost, unattended process, low upholding, easy installation, and extended life. These are all vital in remote position where electricity may be unavailable. So far, in the development of this research, the center of attention has been to estimate the available radiation at a particular site on the earth's surface and then analyzed the characteristics of a photovoltaic generator and a photovoltaic network. The principle of this research is to examine all the essential steps and key components desired to design and build a pump by means of photovoltaic system.**

Keywords—: Solar water pumping, PV module, structure, wiring, storage tank.

I. INTRODUCTION (*Heading 1*)

It is common to use diesel in rural areas to run pump sets in agricultural operations. These systems have some momentous drawbacks, such as fuel has to be transported to the pumping location, which may be quite a distance over some challenging roads and landscape. Their noise and fumes can disturb livestock. Pumps require a significant amount of maintenance and, like all mechanical systems; they break down and need replacement parts that are not always available. For many agricultural needs, the alternative is solar energy. Modern, well-designed, simple to- maintain solar systems can provide the energy where it is needed, and when it is needed. In general, there are two types of solar systems – those that convert solar energy to D.C. Power and those that convert solar energy to heat. Both types have many applications in agricultural settings, making life easier and helping to increase the productivity. First is solar generated electricity, called photovoltaic (or PV). Photovoltaic are solar cells that convert sunlight to D.C. electricity. The solar cells in a PV module are made from semiconductor materials. When light energy strikes the cell, electrons are knocked loose from the material's atoms. Electrical conductors attached to the positive and negative sides of the material allow the electrons to be captured in the form of a D.C. current. This electricity can then be used to power a load, such as a water pump, or it can be stored in a battery .It's a simple fact that PV modules produce electricity only when the sun is shining, so some form of energy storage is necessary to operate systems at night by means of battery or any energy saving device. [1].

II. WATER PUMPING AND WATER PUMPING SYSTEM

Water pumping is one of the simplest and most appropriate uses for photovoltaic. From crop irrigation to stock watering to domestic uses, photovoltaic-powered pumping systems meet a broad range of water needs. Most of these systems have the added advantage of storing water for use when the sun is not shining, eliminating the need for batteries, enhancing simplicity and reducing overall system costs. Many people considering installing a solar water pumping system are put off by the expense. Viewing the expense over a period of 10 years, however, gives a better idea of the actual cost. By comparing installation costs (including labour), fuel costs, and maintenance costs over 10 years, you may find that solar is an economical choice. A solar-powered pumping system is generally in the same price range as a new windmill but tends to be more reliable and require less maintenance. A solar-powered pumping system generally costs more initially than a gas, diesel, or propane-powered generator but again requires far less maintenance and labour. [2]

There are two basic types of solar-powered water pumping systems.

- Battery-coupled water pumping systems
- Direct-coupled water pumping systems

Battery-coupled water pumping systems consist of photovoltaic (PV) panels, charge control regulator, batteries, pump controller, pressure switch and tank and DC water pump (Figure 1). The electric current produced by PV panels during daylight hours charges the batteries, and the batteries in turn supply power to the pump anytime water is needed. The use of batteries spreads the pumping over a longer period of time by providing a steady operating voltage to the DC motor of the pump. Thus, during the night and low light periods, the system can still deliver a constant source of water for livestock.

The use of batteries has its drawbacks. First, batteries can reduce the efficiency of the overall system because the operating voltage is dictated by the batteries and not the PV panels. Depending on their temperature and how well the batteries are charged, the voltage supplied by the batteries can be one to four volts lower than the voltage produced by the panels during maximum sunlight conditions. This reduced efficiency can be minimized with the use of an appropriate pump controller that boosts the battery voltage supplied to the pump. [4]

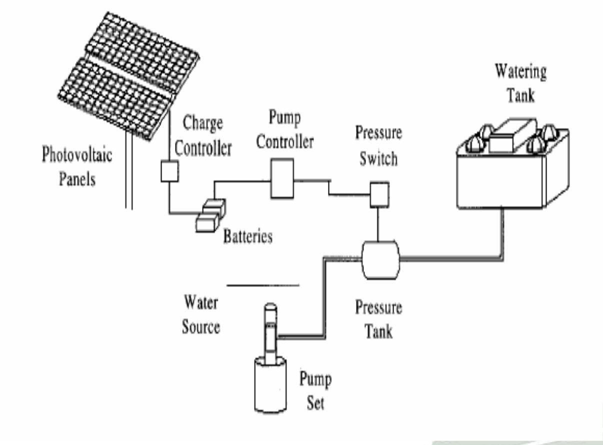


Fig. 1. Battery-coupled water pumping system

In direct-coupled pumping systems, electricity from the PV modules is sent directly to the pump, which in turn pumps water through a pipe to where it is needed (Figure 2). This system is designed to pump water only during the day. The amount of water pumped is totally dependent on the amount of sunlight hitting the PV panels and the type of pump. Because the intensity of the sun and the angle at which it strikes the PV panel changes throughout the day, the amount of water pumped by this system also changes throughout the day. For instance, during optimum sunlight periods (late morning to late afternoon on bright sunny days) the pump operates at or near 100 percent efficiency with maximum water flow. However, during early morning and late afternoon, pump efficiency may drop by as much as 25 percent or more under these low-light conditions. During cloudy days, pump efficiency will drop off even more. To compensate for these variable flow rates, a good match between the pump and PV module(s) is necessary to achieve efficient operation of the system. Direct-coupled pumping systems are sized to store extra water on sunny days so it is available on cloudy days and at night. Water can be stored in a larger-than-needed watering tank or in a separate storage tank and then gravity-fed to smaller watering tanks. Water-storage capacity is important in this pumping system. Two to five days' storage may be required, depending on climate and pattern of water usage. Storing water in tanks has its drawbacks. Considerable evaporation losses can occur if the water is stored in open tanks, while closed tanks big enough to store several days water supply can be expensive. Also, water in the storage tank may freeze during cold weather. [4]

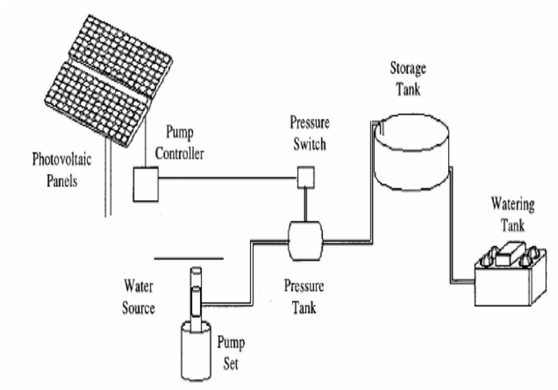


Fig. 2. Direct-coupled water pumping systems

III. Designing A Solar Powered Pumping System

Basic Steps to Designing a Solar Powered Pumping system:

1) Determine your needed FLOW.

2) Determine your needed PRESSURE

3) Select a PUMP that will provide the needed flow and pressure

4) Supply enough PV capacity to power the pump to provide the needed flow and pressure.

IV. Components Of Solar Water Pumping System

A. Solar Modules OR Solar panel OR Photovoltaic panels

Solar electric systems are sometimes called photovoltaic systems. The word "photovoltaic" is often abbreviated PV. Most solar panels, or modules, generate direct current (DC) electricity. A group of modules is called an array. Each solar cell has two or more specially prepared layers of semiconductor material that produce direct current (DC) electricity when exposed to light. This DC current is collected by the wiring in the panel. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines, or stored in batteries for later use by the pump.

Manufacturers normally rate voltage (volts) and current (amps) output from PV panels under peak power conditions. Peak power (watts=volts x amps) is the maximum power available from the PV panel at 1000 W/m² solar irradiance (amount of sunshine) and a specified temperature, usually 25 C (77 F). Typical output from a 60-watt PV panel is shown in Table 1. The amount of DC current produced by a PV panel is much more sensitive to light intensity striking the panel than is voltage generated. Roughly speaking, if you halve the light intensity, you halve the DC current output, but the voltage output is reduced only slightly. [5]

TABLE I. Output From A 60-Watt, 24-Volt Photovoltaic Panel

Maximum Power	60Watts
Maximum power Voltage	17 Volts
Maximum power Current	2.3 Amps

B. Mounting Structures and wiring

There are two ways to mount solar modules: either on a fixed structure or on a tracking structure. Fixed mounts are less expensive and tolerate higher wind loading but have to be carefully oriented so they face true south (not magnetic south).

An array can easily be mounted on a trailer to make it portable. A tracking array follows the sun across the sky. A tracker will add at least Rs. 20000 to Rs.50000 to the cost of a system, but can increase water volume by 25 percent or more in the summertime, compared to a fixed array. [7]

Fig. 3 Solar Panel

Fig.4. Structure

C. Solar (DC) water pump

The other major component of these systems is the pump. Solar water pumps are specially designed to use solar power efficiently. Conventional pumps require steady AC current that utility lines or generators supply. Solar pumps use DC current from batteries and/or PV panels. In addition, they are designed to work effectively during low-light conditions, at reduced voltage, without stalling or overheating. Although wide ranges of sizes are available, most pumps used in livestock-watering applications are low volume, yielding 7-15 liters of water per minute. Low volume pumping keeps the cost of the system down by using a minimum number of solar panels and using the entire daylight period to pump water or charge batteries. Some solar pumps are fully submersible, while others are not. The use of submersible pumps eliminates potential priming and freezing problems. Most solar water pumps are designed to use solar power most efficiently and operate on 12 to 36 volts DC. Centrifugal-type pumps that impart energy to the water using a rotating impeller are typically used for low-lift or high-volume systems. Centrifugal pumps start gradually and their flow output increases with the amount of current. For this reason, they can be tied directly to the PV array without including a battery or controls. However, because their output drops off at reduced speeds, a good match between the pump and PV array is necessary to achieve efficient operation. Pumps, because of their mechanical nature, have certain well-defined operating properties. These properties vary between types of pumps, manufacturers, and models. The amount of water that a solar pumping system will deliver over a given period of time (usually measured in liters per minute (LPM) or liters per hour (LPH)) depends upon the pressure against which the pump has to work. The system pressure is largely determined by the total vertical pumping distance (the vertical distance between the water source and the watering tank) referred to simply as elevation head. [5]

In selecting a pump, the following parameters should be considered:

- The required capacity or flow rate—how many gallons per minute (or per day) are needed.
- The conditions on the suction side of the pump (lots of grit, sand, or dissolved minerals in the water; algae growth; etc.).
- Whether the pump will be submersible in a well or pump from a surface source.
- The total head capability (how high can the pump move water).
- Space, weight, and position limitations, as well as cost of equipment and installation.
- Codes and standards, including the National Electrical Code (Wiles, 2001).
- The voltage(s) and power required for the pump and its working efficiency. [6]

The expected flow rates and minimum recommended solar panel sizes for a typical 24-volt, pump are shown in Table 2. The choice of pump depends on water volume needed, efficiency, price, and reliability.

D. Battery

You are bidding one brand new 12 Volt 7 Amp Hour Triumph Battery. This battery is perfect for wheelchairs, UPS systems, robots, phone systems, pool vacuums and much more. They are manufactured by Rhino Battery Company. This is a brand new battery in the factory sealed box. These batteries are not distressed stock, they were made last month. Dimensions are length-5.95, width-2.56, and height-3.86 inches. Weight is approx. 5.94 lbs. This battery pack consists of 12 volt 7 amp hour sealed lead acid battery.

E. Storage tank

Storage tanks are containers that hold liquids, water or mediums used for the short- or long-term storage of water or liquid for pumping from low to high altitude. The term can be used for reservoirs (artificial lakes and ponds), and for manufactured containers.

Depending on the climate and usage, storage capacity should equal three to ten days of water. For domestic use in a cloudy climate, ten days may be necessary while for sunny climates, three days-of-storage for livestock watering may be sufficient. For deep irrigation such as that for trees (where the soil holds moisture for a week) three days' storage may be adequate. For irrigating a home garden, perhaps five days may be required. The storage tank size is calculated by multiplying days-of-storage by the daily water requirement.

F. *Controller or Inverter*

The pump controller protects the pump from high- or low-voltage conditions and maximizes the amount of water pumped in less than ideal light conditions. An AC pump requires an inverter, an electronic component that converts DC electricity from the solar panels into AC electricity to operate the pump. [4]

G. *Other equipment*

A float switch turns a pump on and off when filling the stock tank. It's similar to the float in a toilet tank but is wired to the pump controller, and piping arrangement for pumping of water and voltmeter for measurement currant and voltage. Low water cut-off electrodes protect the pump from low water conditions in the well. [7]

V. SYSTEM SIZING

Before choosing the final components, the system should be roughly sized to allow viewing of approximate component sizes. Later, the components must be sized again by a detailed electrical and mechanical design. The purpose of this chapter is to provide simple tools to roughly estimate the needed system size before contacting a PV specialist.

The approach is to estimate the required component size by making assumptions about the efficiency of all key components and by using monthly average weather data.

To make the procedure easier, a set of data has been prepared for the different steps. [5]

- Specification of site conditions
- Estimation of the electricity demand
- Sizing of grid-connect system
- Sizing of battery
- Sizing of array an components

VI. DESIGNING AND INSTALLING SYSTEMS

Every pumping and stock-watering situation is unique. The average consumer is likely to be intimidated by the prospect of sizing and designing a solar pumping system, and most people need the assistance of a qualified solar dealer. In general dealers are eager to help. Many will provide a no-cost proposal based on a few simple questions that can be asked over the phone. If the price seems too high, you can easily get bids from other dealers. In order to size and design a system correctly, the dealer will want to know:

- How much water you need;
- When you need the water;
- Whether your water source is a stream, pond, spring, or well;
- Water available in gallons per minute (gpm);
- Well depth;
- How far the water needs to be pumped, and with what elevation gain;
- Water quality problems (e.g., silt or high mineral content) that may damage the pump;
- How much volume is available in storage tanks and how the tanks are arranged?

Installing a solar pump is a complex task, combining elements of electrical work, plumbing, and heavy construction (often including earthmoving, pouring concrete, and welding). Written instructions are not always as complete as they should be. A backhoe or tractor with a front-end loader is almost a necessity for some larger projects. [8].

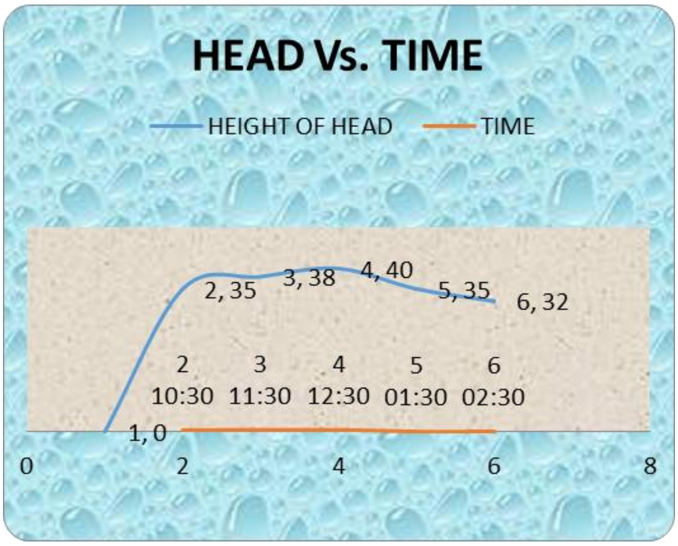
VII. ANALYSIS OF SYSTEM

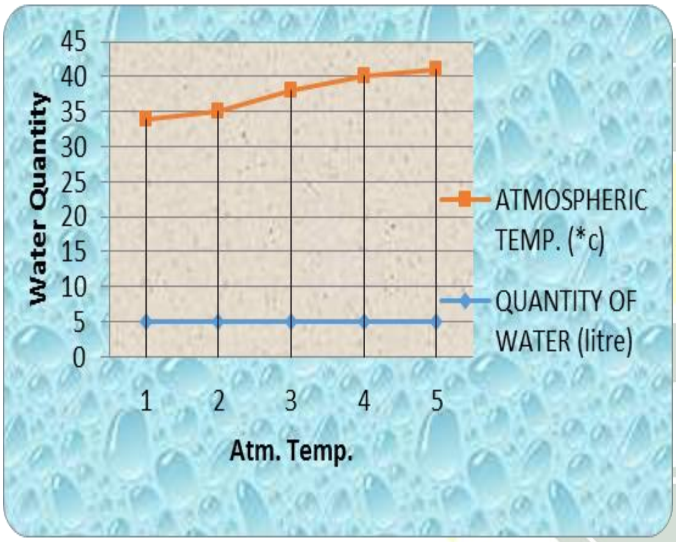
TABLE II. ESTIMATED VALUE ON THURSDAY

DAY	QUANTITY OF WATER (litre)	ATMOSPHERIC TEMP. (*c)	HEIGHT OF HEAD (cm)	TIME	CURRENT (amp.)	VOLTAGE (volt)
Thursday	5	29	35	10:30 am	2.31	11.87
Thursday	5	30	38	11:30 am	2.52	12.31
Thursday	5	33	40	12:30 am	2.41	12.11
Thursday	5	35	35	01:30 am	2.73	11.56
Thursday	5	36	32	02:30 am	2.55	11.91

TABLE III. ESTIMATED VALUE ON FRIDAY

DAY	QUANTITY OF WATER (litre)	ATMOSPHERIC TEMP. (*c)	HEIGHT OF HEAD (cm)	TIME	CURRENT (amp.)	VOLTAGE (volt)
Friday	5	36	40	11:45	2.41	11.97
Friday	5	37	38	12:45	2.51	12.01
Friday	5	38	39	01:45	2.69	12.03
Friday	5	38	38	02:45	2.72	12.03
Friday	5	37	39	03:45	2.61	11.88





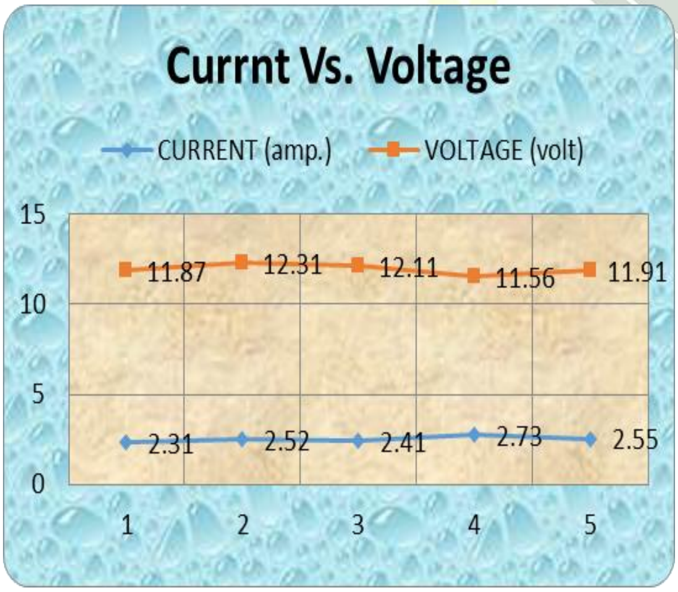


Fig. 5, 6, 7 Graphical Representation of Data's

VIII. Basic Features And Benefits Of The System

- The system pumps out 100 Liters of water per day (Assuming 6 hours of available sunlight) at 5 meters lift.
- System productivity increases in summers when water requirement is usually greater.
- Life of 20 years hedges future costs and uncertainties.
- Requires minimal service and maintenance
- Breakeven against conventional diesel pumps as low as three years
- Powered by clean, renewable energy

IX. Future Scope

Since the increase in price per increase in unit power output of a photovoltaic system is greater than that for a diesel, gasoline, or electric system, photovoltaic power is more cost spirited when the irrigation system with which it operates has a low total dynamic head. For this reason, photovoltaic power is more cost-spirited when used to power a micro irrigation system as compared to an overhead sprinkler system. Photovoltaic power for irrigation is cost-spirited with conventional energy sources for small, remote applications, if the total system design and utilization timing is carefully considered and organized to use the solar energy as efficiently as possible. In the future, when the prices of fossil fuels rise and the economic advantages of mass production reduce the peak watt cost of the photovoltaic cell, photovoltaic power will become more cost-competitive and more common.

Conclusion

The output of a solar pumping system is very reliant on good system design resulting from precise site and demand data. It is therefore essential that precise assumptions are made relating to water demand/pattern of use and water accessibility including well acquiesce and expected drawdown.

With a solar pump, energy is not available on demand, and the daily disparity 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 of lifted water in a storage tank. The aptness of solar power for lifting water to irrigate plants is undeniable because of the complementary between solar irradiance and water requirements. The more intensively the sun is shining the higher is the power to supply water while on the other hand on rainy days water for irrigation is neither possible nor needed.

Water pumping has long been the most steadfast 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 radiating radiation. Most PV pumping systems do not use batteries – the PV modules power the pump directly.

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