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Feature Article

SOLAR POWERED WATER PUMPING SYSTEMS

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ABSTRACT

Agricultural technology is changing rapidly. Farm machinery, farm building and production facilities are constantly being improved. Agricultural applications suitable for photovoltaic (PV) solutions are numerous. These applications are a mix of individual installations and systems installed by utility companies when they have found that a PV solution is the best solution for remote agricultural need such as water pumping for crops or livestock. A solar powered water pumping system is made up of two basic components. These are PV panels and pumps. The smallest element of a PV panel is the solar cell. 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. The aim of this article is to explain how solar powered water pumping system works and what the differences with the other energy sources are.

Key words: Agriculture, water, solar cell, pump

INTRODUCTION

It is common to use diesel to power generators in agricultural operations. While these systems can provide power where needed, there are some significant drawbacks, including:

- Fuel has to be transported to the generator's location, which may be quite a distance over some challenging roads and landscape.
- Their noise and fumes can disturb livestock.
- Fuel costs add up, and spills can contaminate the land.
- Generators require a significant amount of maintenance and, like all mechanical systems, they break down and need replacement parts that are not always available.

There are also major disadvantages in using propane or bottled gas to heat water for pen cleaning or in crop processing applications, or to heat air for crop drying, including transportation to the location where you need the heat, costs of fuel and safety issues.

For many agricultural needs, the alternative is solar energy. Modern, well-designed, simple-to-maintain solar systems can provide the energy that is needed where it is needed, and when it is needed. These are systems that have been tested and proven around the world to be cost-effective and reliable, and they are already raising levels of agricultural productivity worldwide (**Figure 1**).

***Figure 1**. A range and solar system are side by side [1]*

In general, there are two types of solar systems – those that convert solar energy to D.C. power and those that convert solar

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energy to heat. Both types have many applications in agricultural settings, making life easier and helping to increase the operation's 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 [2]

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. You can store the energy as water by pumping it into a tank while the sun is shining and distributing it by gravity when it's needed after dark. For electrical applications at night, you will need a battery to store the energy generated during the day (**Figure 2**).

***Figure 2**. A typical assembly of solar cells [3]*

Photovoltaic is a well-established, proven technology with a substantial international industry network. And PV is increasingly more cost-effective compared with either extending the electrical grid or using generators in remote locations. The cost per peak watt of today's PV power is about $7. Local supply conditions, including shipping costs and import duties, vary and may add to the cost.

PV systems are very economical in providing electricity at remote locations on farms, ranches, orchards and other agricultural operations. A "remote" location can be as little as 15 meters from an existing power source. PV systems can be much cheaper than installing power lines and step-down transformers in applications such as electric fencing, area or building lighting, and water pumping – either for livestock watering or crop irrigation.

WATER PUMPING

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 [4]. The cost of solar-pumped water per cow ranged from $0.03 to $0.15 per day. The cost per gallon of water pumped ranged from $0.002 to $0.007 per gallon.

Solar-Powered Water Pumping System Configurations

There are two basic types of solar-powered water pumping systems, battery-coupled and direct-coupled. A variety of factors must be considered in determining the optimum system for a particular application [1].

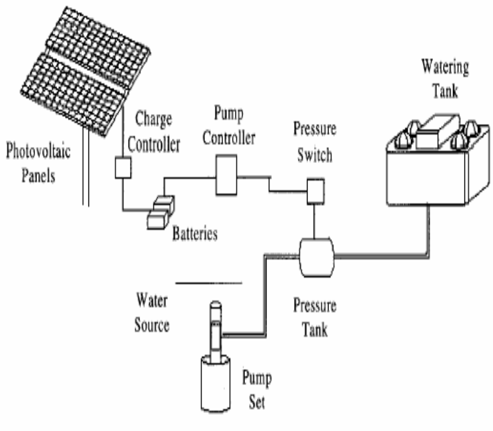

***Figure 3.** Battery-coupled solar water pumping system [5]*

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 3**). 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.

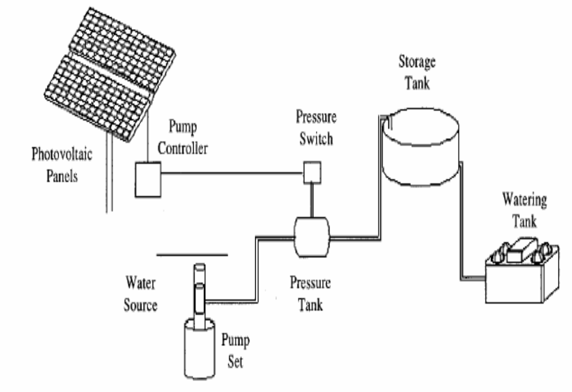

Figure 4. *Direct coupled solar pumping system [5]*

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 4**). 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.

Main solar powered stock watering system components

A typical solar-powered stock watering system includes a solar array, pump, storage tank and controller [6], (**Figure 5**).

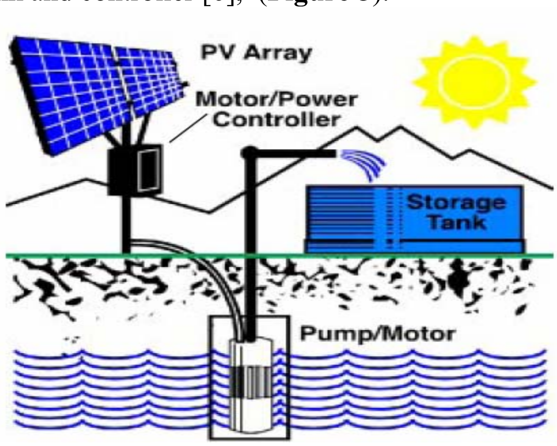

Figure 5*. A typical solar-powered stock watering system [1]*

Solar Modules

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.

Mounting Structures

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 $400 to $800 to the cost of a system, but can increase water volume by 25 percent or more in the summertime, compared to a fixed array.

Pumps

DC water pumps in general use one-third to one-half the energy of conventional AC (alternating current) pumps. DC pumps are classed as either displacement or centrifugal, and can be either submersible or surface types. Displacement pumps use diaphragms, vanes or pistons to seal water in a chamber and force it through a discharge outlet. Centrifugal pumps use a spinning impeller that adds energy to the water and pushes into the system, similar to a water wheel. Submersible pumps, placed down a well or sump, are highly reliable because they are not exposed to freezing temperatures, do not need special protection from the elements, and do not require priming. Surface pumps, located at or near the water surface, are used primarily for moving water through a pipeline. Some surface pumps can develop high heads and are suitable for moving water long distances or to high elevations.

Storage

Batteries are usually not recommended for solar-powered livestock watering systems because they reduce the overall efficiency of the system and add to the maintenance and cost. Instead of storing electricity in batteries, it is generally simpler and more economical to install 3 to 10 days' worth of water storage.

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.

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. Low water cut-off electrodes protect the pump from low water conditions in the well.

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.

CONCLUSION

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 competitive when the irrigation system with which it operates has a low total dynamic head. For this reason, photovoltaic power is more cost-competitive when used to power a micro irrigation system as compared to an overhead sprinkler system. Photovoltaic power for irrigation is cost-competitive with traditional energy sources for small, remote applications, if the total system design and utilisation timing is carefully considered and organised 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.

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