Photovoltaic Water Pumps

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RURAL WATER SUPPLY

In many developing countries, the inadequate supply of drinking and irrigation water is a severe problem. In rural areas with no access to grid power, national water authorities and private farmers have to rely on hand pumps and diesel-driven pumps, many of which are out of service due to technical defects or a lack of fuel.

As a rule, hand-operated pumps are the least-cost option for low consumption rates and low pumping heads. If hand pumps cannot satisfy the demand, diesel-driven pumps are commonly used for drinking and irrigation water supply. These pumps stand in competition with photovoltaic water pumps (PVP), which present themselves as a reliable and environmentally-sound alternative means of water delivery.

GOOD REASONS FOR PVP-APPLICATION

PVP systems offer numerous advantages over water supply systems utilising conventional power:

❑ PVP systems may be the only practical water supply solution in many regions where the logistics make it too expensive or even impossible to supply diesel generators with the required fuel.

❑ PVP systems are ideal for meeting water requirements for villages between 500 and 2000 inhabitants and small-scale irrigation purposes (up to 3 hectares).

❑ PVP systems run automatically, require little maintenance and few repairs

❑ In areas where PVPs have entered into competition with diesel-driven pumps, their comparatively high initial cost is offset by the achieved savings on fuel and reduced maintenance expenditures

❑ The use of solar energy eliminates emissions and fuel spills

Taken together, these reasons can persuade water authorities as well as private investors to decide in favour of a PVP system as against conventional pumping techniques.

HOW A PVP-SYSTEM WORKS

The operating principle behind any photovoltaic pumping system is quite simple (see fig. 1). A solar generator provides electricity for driving a submersible motor pump, which in turn pumps water into an elevated water tank that bridges night-time periods and cloudy days.

Force of gravity causes the water to flow from the tank to public water taps and watering points for livestock or to the irrigation system.

One major advantage of solar pumps is that they do not require batteries, which are expensive and need a lot of maintenance. The maintenance of a PVP system is restricted to regular cleaning of the solar modules. Depending on the water quality, the only moving part of the system, the submersible motor pump, has to be checked every 3 to 5 years.
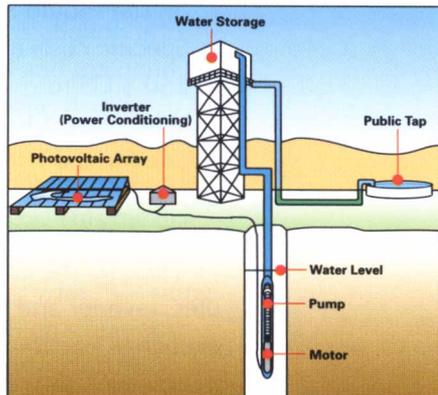
POWER OF PV GENERATOR	PUMPING HEAD	DAILY WATER OUTPUT *
1 kWp	10 m	50 m³
	30 m	15 m³
	50 m	10 m³
2 kWp	10 m	100 m³
	30 m	35 m³
	50 m	20 m³
3 kWp	10 m	160 m³
	30 m	50 m³
	50 m	30 m³

* FOR CLEAR, SUNNY DAYS

Figure 1: PVP standard system

On a clear, sunny day, a medium-size PVP system with an installed power of 2 kW_p will pump approximately 35 m³ of water per day to a head of 30 meters. That amount of water is sufficient for communities with populations up to 1400. Additional performance data for the various system designs are indicated in the table.

Today's generation of PVP systems is highly reliable [1]. For the most costly part, the PV generator, the manufactures give a 20 year guarantee on the power output. A crucial prerequisite for the reliability and economic efficiency is that the system be sized appropriate to the local situation.

SIZING A PVP-SYSTEM

The PVP system is sized on the basis of the findings from a local data survey. While an on-site survey of meteorological and climatic data would be worthwhile in any case, it is usually thwarted by a lack of time and money. Many systems are based on the known data of a nearby reference location for which relevant measured values are available. If it is possible to visit the intended location, the following field data should be gathered:

- water quality
- demand for water in the supply area
- pumping head with allowance for friction losses and well dynamics
- geographical peculiarities, e.g., valley locus

It is also important to include sociological factors in the planning process. The future users should be involved in the data-gathering process at the intended PVP site in order to make early allowance for their customs and traditions in relation to water. Women in particular must be intensively involved in the planning, because they are the ones who are usually responsible for maintaining hygiene and fetching water. Thus, the planning base for each different location should cover both technical _and_ sociological aspects.

The technical planner can choose from a number of design methods of various quality. The most commonly employed approaches are outlined below.

Estimation of PV Generator Output

To arrive at a first estimate of how much the planned PVP system will cost for a just-selected site, it is a good idea to first estimate the requisite size of the PV generator. This, however, presumes knowledge of the essential sizing data, namely the daily water requirement within the area of supply (V_d), the pumping head to be overcome by the pump (H), and the mean daily total of global irradiation (G_d) for the design month.

A simple arithmetic formula allowing for the individual system component efficiencies can be used to calculate the required solar generating power P_{SG}. The equation reads:

$$P_{SG} = 11.6 * \frac{H * V_d}{G_d}$$

According to this equation, it takes a 3.5-kW$_p$ PV generator to deliver water at the rate of 30 m³/d at a head of 50 m for a daily total global irradiation of 5 kWh/(m²*d). This gives the planner an instrument for estimating the size of the PV generator and, hence, the cost of the planned system at the time of site selection.

Graphic Sizing / Nomograms

Several suppliers developed product-specific system design diagrams that simplify the planning task by enabling quick and easy sizing of the equipment (fig. 2).
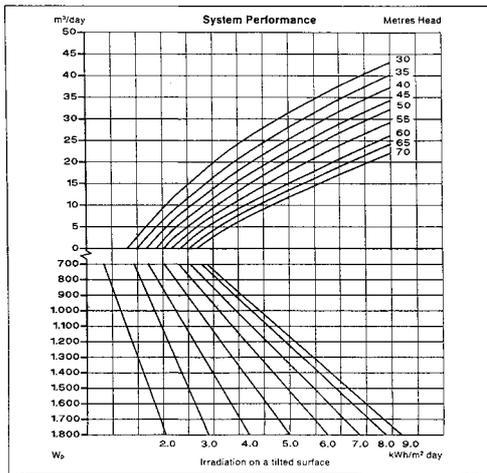
Figure 2: System performance curves (Source: GRUNDFOS)

Such diagrams cannot, of course, help arrive at a site-appropriate design, because they make no allowance for diurnal variation in terms of pumping heads, temperatures, wind velocities and irradiation rates. The design of systems with the aid of GRUNDFOS plots produced standard deviations on the order of 27 % [2]. Systems designed with the site-specific time-of-day dynamics in mind are therefore better.

Computer-Aided Sizing Programs

Computer-aided system simulations facilitate the otherwise laborious sizing process. The available software includes everything from simple demonstration programs to highly flexible free-style programs.
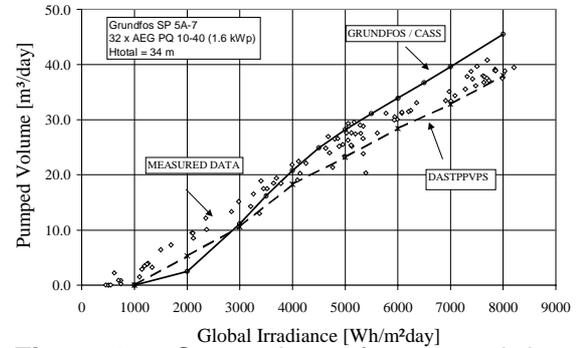
Figure 3: Comparison of measured data and computer design results using *DASTPVPS* and *Grundfos-CASS* software.

The quality and the utility value of design programs depend on how closely the results of simulation coincide with reality. Good agreement was noted between real operating data and the computer-simulated data obtained using the DASTPVPS simulation and design program developed by the German *Universität der Bundeswehr* in Munich [3]. DASTPVPS can serve technical planners as a suitable instrument for system design and for checking the performance of PVPs. Operational data analyses indicate that a properly designed standardised PVP system can be expected to achieve an overall efficiency (24 h) above 3 %.

ECONOMIC CONSIDERATIONS

Although the advantages of solar technology are evident, purchase decisions are often taken in favour of the competing diesel-powered systems. The comparatively high investment costs of the solar system are critical here.

Investment Costs

Figure 4 shows the price of a PVP system related to power generation. Today the operator of a ready-to-use solar pump pays about 3 times as much as would be needed for a diesel pump with the same performance [4].
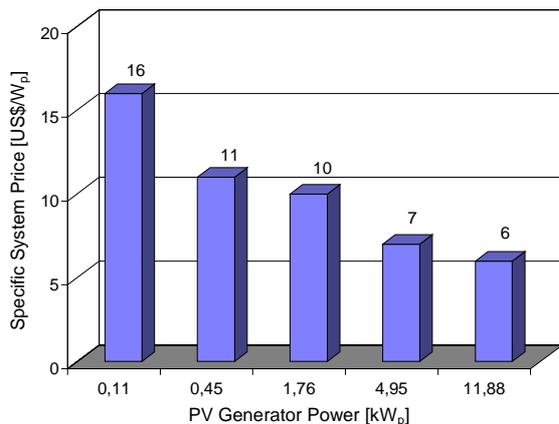
Figure 4: Specific PVP system prices (ex-works) without water tank, fence and surface piping (Source: Siemens Solar)

However, it is frequently overlooked that after installation the solar system incurs only a fraction of the operating costs of a diesel pump. Consequently it does not make economic sense to compare different technologies solely on the basis of the investment costs.

Specific Water Discharge Costs

The specific water discharge costs [Euro/m^4], covering both investment and operating costs, are taken as a basis for comparing the costs of solar and diesel pumps. Furthermore, the specific water discharge costs permit an evaluation of different pumping technologies, even for sites involving different pumping heads and degrees of utilization.

The costs per cubic metre supplied are obtained by multiplying with the pumping head at the relevant location. In the drinking water sector GTZ has demonstrated the cost advantages of solar pumps in the performance range up to 2 kW$_p$ in six out of seven project countries (Asia, Africa, Latin America) [4]. First results of photovoltaic water pumps applied in small-scale irrigation systems are promising [5]. However, due to the variability of country and site-specific cost factors, no generally valid conclusion can be drawn with regard to the overall viability of photovoltaic pumps.

PERSPECTIVES OF PVP TECHNOLOGY

In regions with high insolation levels, electricity from solar cells opens up new options for pumping water. Photovoltaic pumping systems are technically fit for use, beneficial for the environment and are able to yield cost advantages over diesel-driven pumps, as long as certain site-specific conditions apply. However, the high initial investment costs are still the main obstacle to distribution of PV pumps. Therefore it is necessary to compensate for the high investment costs by providing loans on favourable terms via development banks or through other suitable financing models.

Besides the purely financial evaluation, additional criteria are needed for an overall evaluation of PVP-technology. Fuel and lubricants for diesel pumps often pollute wells, soil and groundwater. By contrast, photovoltaic pumps are an environmentally sound and resource-conserving technology. Contamination of soil and ground-water resources can be completely avoided when deciding in favour of the PVP option.

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