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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Performance evaluation of solar water pumps

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Water pumping with solar power is not very popular in Sri Lanka mainly due to their poor performance despite having most favourable climatic conditions .for the same. The controlled tests carried out with a typical solar water pumping system indicated that photo voltaic modules consistently attained the performance levels specified by the manufacturers, while the pump performed at noticeably lower levels. Further, the high initial cost of solar water pumping systems when compared to alternative sources is a major obstacle in the widespread use of this renewable energy technology.

Introduction

There has been a greater awareness in recent times of the need to utilize renewable energy sources for such purposes as water supply. Despite the comparatively high initial cost, solar-powered water pumps are particularly attractive to rural poor in distant isolated villages without access to main electric grid.

In a solar powered water pumping system, a photo voltaic (PV) array, also known as solar modules or panels, convert solar energy directly into electricity to power a water pump. Water pumps, which are custom made for solar power and PV modules are available for a wide range of head-discharge requirements.

In the early eighties, solar water pumping was introduced to Sri Lanka on a commercial basis. However, its use to date has been very low despite the country having most favourable climatic conditions for the same. One reason for this could be that solar water pumping systems seem to fall short of manufacturers' specifications. The authors' observations appear to indicate that a solar water pump installed at the Moratuwa University premises is one such example. Similar situations have been also reported in Botswana (Hodgkin et aI., 1988).

Therefore, there is a need for controlled laboratory tests on solar water pumping systems to understand their characteristics and associated problems, particularly in Sri Lankan conditions.

Objectives of the study

The primary objectives of the present study are: (1) to measure and evaluate the technical performance of a typical solar water pumping system, and, (2) to identify the problems associated with solar water pumping.

Laboratory tests

Pump selected for the study

The solar water pump selected for the study was a typical medium head, direct current operated pump. Specifications of the pump and the solar panels as given by the respective manufacturers are summarized in Table 1.

Testing methodology and instrumentation

Laboratory tests aimed at determining the pump performance were carried.

The pump was submerged in the sump beneath the floor of the laboratory, which simulated the well, and the delivery pipe discharged to a flow measuring device and back to the sump (See Figure 1.).

The delivery head of the pump was varied within the specified range by changing the discharge pressure. For this purpose, a 50 mm gate valve, associated with a pressure gauge was connected to the delivery pipe. The pressure head could be varied by adjusting the valve. The discharge from the pump was obtained by recording the time taken to collect a known volume of water into the barrel.

It was difficult to test pump characteristics with power directly from the solar panels, as the light intensity and therefore the output power from the solar array varied frequently. Therefore, to maintain a constant power supply, two 45 Ampere-Hour batteries connected in series with a variable resistor were used independent of the solar array.

Table 1. Manufacturer's specifications for pump and solar module

Pump: Type Operating Voltage Operating Current Performance	 Submersible pump, 375 W at peak 13.6 – 15.6 Volts DC 20 – 24 Ampere 360 l/min. at 2 m Head 225 l/min. at 5 m Head
Solar module	12 Volts DC nominal, 2.15 Ampere, 35 W (peak) modules

A voltmeter and an ammeter measured the supply voltage and current to the pump, respectively.

The method used to relate the pump performance obtained as mentioned above with the battery power, to that with solar energy, is outlined in the following. Computations indicated that a 12 module solar array with an open circuit voltage of 18 Volts and a short circuit current of 27 Amperes was required to power the pump. An array, capable of delivering the above requirement, was mounted sloping towards the equator at 18 degrees to the horizontal (following the recommendations given in Siemens Training Manual, 1990, and Kenna and Gillett, 1988) as shown in Figure 2. Then the solar array was connected to the pump and allowed to operate for 30 seconds. The prevailing solar intensity and the corresponding operating voltage and current at the pump terminals were recorded at every 5 second intervals during this period. A digital meter (SOLAR 118) was used to measure the instantaneous solar intensity. This was repeated for different sunlight levels, covering 100 to 800 Watts per square meter and for each set, 30 second average values were computed. Thus the relation between the pump performance and the solar intensity could be established because they are related to the operating voltage and current in both cases.

Results and discussion

Experimental data relating head, discharge, input power, solar intensity, etc., were collected, and the most pertinent results that define the basic characteristics of the pumping system are presented in graphical form in the following.

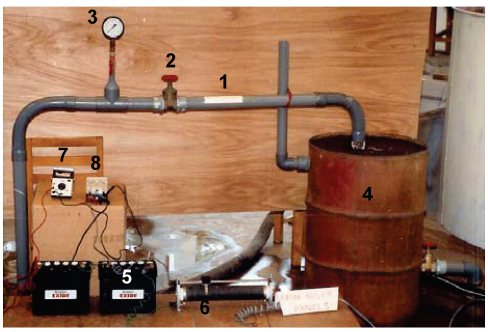

Figure 1. Pump testing system: (1) Delivery pipe, (2) Gate valve, (3) Pressure gauge, (4) Barrel, (5) Batteries, (6) Variable resistor, (7) Ammeter

Figure 2. Solar array used in testing

Head-discharge characteristics

The observed head-discharge characteristic of the pump is shown in Figure 3 along with the performance specified by the manufacturer. Clearly, the observed discharges are much less than the specified value. Apparently, this was the problem with the university solar water pump mentioned earlier. It must be added that Hodgkin et al. (1988) reported similar observations in a study carried out in Botswana on solar water pumping.

Variation of efficiency with head

The plot of the overall efficiency with delivery head in Figure 4 indicates that this particular pump works most efficiently at 3 to 4 meters of head. The efficiency, μ, is computed as the percentage of the ratio between output power of water and the input electrical power:

$$\mu = \frac{\rho Q g h}{VI}$$

where, g is the acceleration due to gravity, h is the elevation head, I is the input current, Q is the flow rate, and V is the input voltage.

Power from 12-module array with solar intensity

The variation of output power with solar intensity for the 12-module solar array that was required to drive the pump is shown in Figure 5. A single module of this array, consisting of 34 cells yields an open circuit voltage of 19 Volts and a maximum short circuit current of 2.25 Amperes.

Figure 5 presents the measured power output of solar array with respect to the load condition. The 'no-load' curve shows the power output when the pump is not connected to the panels, i.e., when the panels are not loaded. Therefore, the 'no-load' curve may be considered as giving the variation with the radiation level of the maximum possible power from the array. However, we can observe a drop in the power output when the pump is connected to the solar array, i.e.,

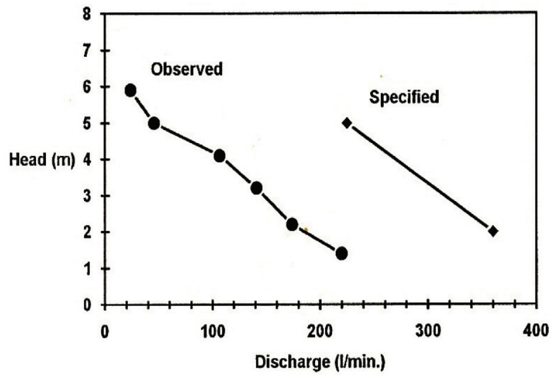

Figure 3. Head-discharge characteristics

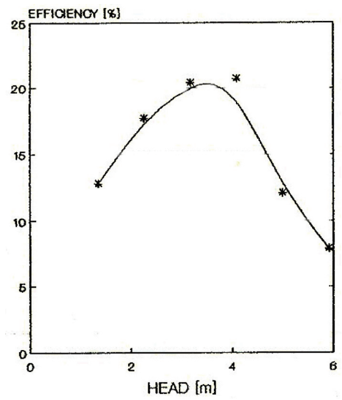

Figure 4. Variation of efficiency with head

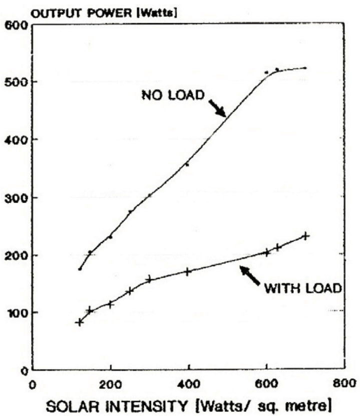

Figure 5. Variation of output power with solar intensity

when panels are loaded.

Therefore we compute the output power at no-load and the output power with load as follows:

Output power at no-load = open circuit voltage x short circuit current, of the PV array, and, Output power with load = operating voltage x operating current of the pump when connected to the solar array.

Further, Figure 5 indicates that the power supply range possible with the specified 12-module solar array is generally 75 to 225 Watts, in Sri Lanka. The upper value may be achieved around noon on a cloudless day.

The effective area of the solar array is 4 square meters. The input solar power and the output electrical power from the array can be obtained from Figure 5. Thus the efficiency of the modules works out to be around 10%. The typical range of efficiency for commercially available solar cells is 8 - 12 % (Fahrenbruch, 1983).

In this connection it may be added that the monthly-average solar intensity levels in Sri Lanka are typically high throughout the year, and are also relatively uniform as shown in Figure 6. The two peaks in March and October correspond to the time period when the sun is closest to the earth.

Furthermore, the variation of solar intensity on a typical cloudless day measured at the Moratuwa University premises is shown in Figure 7. We see that, from 8.00 AM to around 12.30 PM the solar intensity rises before beginning to drop. This is owing to the fact that in the morning or evening, the sun is at a lower angle, and the distance light has to pass through the atmosphere might be two or more times the noon time when the sun is directly overhead.

Discharge against input power

The plot of discharge against the input power at several delivery heads (H) is shown in Figure 8. The 12-module solar array specified for the pump is capable of yielding only up to 225 Watts as discussed above. The corresponding operating region that lies to the left of line MN is indicated in the Figure. Clearly, the discharges within this narrow region are fairly low when compared to the actual capacity of the pump. This is a major drawback as the pump will be forced to operate well below its optimum capacity (375 Watts) most of the time, resulting in a low efficiency.

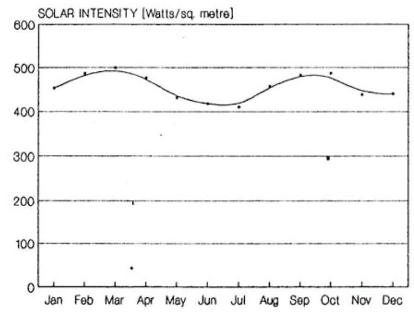

Figure 6. Typical monthly variation of daily average solar intensity in Sri Lanka

Source: Compiled using data given in Siemens Training Manual (1990).

Discharge - Voltage relationship

The pump performance with the supply voltage at several delivery heads (H) is shown in Fig. 9.

However, if we use the recommended solar array to power the pump, the operating voltage range will be below 14.5 Volts most of the time. Therefore, the operating region will be limited to the left of line KL, as indicated in Figure 9. Moreover, if a single battery is used, which is the case very often in Sri Lanka, the operating voltage will be around 12 Volts, thus limiting the working region to an extremely narrow band with low discharges. This is considered to be a major shortcoming in this pump for solar or battery operation because the incremental rise in discharge with the voltage is considerably high as evident in Figure 9.

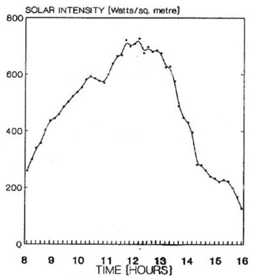

Figure 7. Variation of solar intensity over a typical day

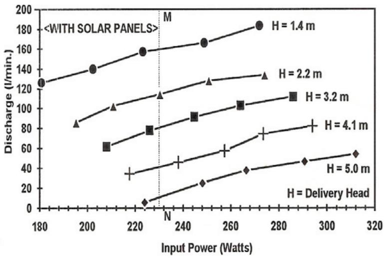

Figure 8. Variation of discharge with input power

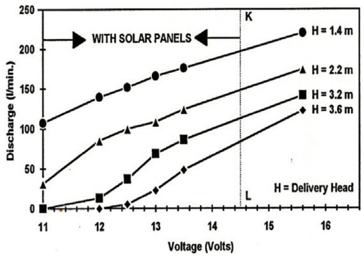

Figure 9. Variation of discharge with input voltage

Conclusions

Sri Lanka is very fortunate in that monthly solar radiation intensity levels throughout the year are fairly high and relatively uniform as was shown in Fig. 6. In addition, water demand is typically greatest during the dry season, when solar intensity levels are highest and most consistent.

Nevertheless, despite this encouraging background, solar water pumping has not become popular in Sri Lanka. One reason for this may be the poor performance of most solar water pumps. Numerous controlled tests carried out using the selected water pumping system further confirmed this.

In the tests, while PV modules consistently attained the performance levels specified by the manufacturers, the pumping system generally performed at noticeably lower levels of discharge and efficiency than that specified by the manufacturers. The authors have observed the same problem with the solar water pump installed at the Moratuwa university premises. Further, as mentioned earlier, Hodgkin et al. (1988) reported similar observations after testing many solar water pumps in Botswana. Therefore, it appears that the manufacturer's performance data may not always be a reliable source of information for system designing at least in some cases.

The recommended solar array for the pump delivered a maximum operating voltage of 14.5 Volts at peak solar intensity. However, the recommended working range for the pump is 13.6 to 15.6 Volts. Further, if a single battery was used, the on-load terminal voltage would be around 12 Volts. This restricts the operating region for the pump to a narrow band, resulting in low discharges.

Therefore, the need to design pumps to match common operating conditions is evident. The operating conditions may include the output potential of solar panels for the most probable intensity levels and the climatic region where the pump will be used.

Apart from technical shortcomings, the other major drawback for a wider use of solar water pumping systems in Sri Lanka is their high initial cost when compared to alternative power sources such as grid electricity and fossil fuel.

Acknowledgment

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