CHAPTER 6

PERFORMANCE OF DOMESTIC SOLAR HOT WATER SYSTEM UNDER WIND ASSISTED SYSTEM MODE

6.1 DETAILS OF THE EXPERIMENTS

In this chapter, a replacement for the electrically operated pump of a Forced Circulation type solar hot water System (FCS) by using a wind mill driven pump is proposed. A two-stage centrifugal pump driven by a vertical axis windmill having Savonius type rotor is added to the fluid loop. The windmill driven pump circulates the water through the collector. The system with necessary instrumentation is tested, as described in Chapter 3, over a day in each month during January to December 2009.

Table 6.1 Details of Experiments with WAS mode

<table>
<thead>
<tr>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time at the beginning of the test</td>
<td>8.30 AM</td>
</tr>
<tr>
<td>Time at the end of the test</td>
<td>4.30 PM</td>
</tr>
<tr>
<td>Time period for calculation</td>
<td>9.00 AM – 4.00 PM</td>
</tr>
<tr>
<td>Reading interval</td>
<td>One hour</td>
</tr>
<tr>
<td>Well mixed tank temperature (initial) at 8.30 AM</td>
<td>Around 26.5°C</td>
</tr>
<tr>
<td>Latitude of location: Pachal, Tamilnadu, India</td>
<td>11.13° N, 78.16° E</td>
</tr>
<tr>
<td>Day of the tests</td>
<td>January, 9, 2009; February, 8; March, 9; April, 9; May, 8; June, 10; July, 10; August, 9; September, 10; October, 10; November, 11; December, 11, 2009.</td>
</tr>
<tr>
<td>Type of wind mill</td>
<td>Vertical axis, Savonius type rotor</td>
</tr>
<tr>
<td>Number of stages</td>
<td>One</td>
</tr>
<tr>
<td>Collector tilt</td>
<td>11.13° facing due south</td>
</tr>
<tr>
<td>Load pattern</td>
<td>No hot water is drawn during the test</td>
</tr>
</tbody>
</table>
The experimental details are given in Table 6.1 and test results of clear days for the months of January, April, July and October are reported in Appendix 5 as sample data. The following sections describe the final outcome of the experiments in WAS mode.

6.2 ATMOSPHERIC DATA

Experiments were conducted during 2009 at Pachal (11.13° N, 78.16° E), Namakkal district, Tamilnadu state, India. The variation of incident solar radiation on the collector plane, atmospheric temperature and wind velocity are presented in Figures 6.1 to 6.6. In the morning around 9.00 AM, solar radiation is in the range of 341 - 434 W/m² and it reaches around 842 – 963 W/m² in the noon and radiation level is reduced to 338 - 540 W/m² in the evening around 4.00 PM. Also, the peak value of incident solar radiation is in the range of 842 – 880 W/m² in the months of October, November, December and January, and in the rest of the year it varies between 928 – 963 W/m². In general solar radiation rises gradually from 9.00 AM and reaches the maximum value around 1.00 PM, finally it drops gradually in the evening. In all the months, distribution of solar radiation is in the form of bell shape curve.

Variation of atmospheric temperature with respect to time of the day is shown in Figures 6.3 and 6.4. At the beginning of the day, around 9.00 AM, the atmospheric temperature varies from 25 - 28.4 °C on the days of the experiment and maximum temperature of around 30.1 - 36.2 °C is found around 1.00 - 2.00 PM. Then, temperature gradually decreases to 29.5 - 33 °C in the evening (at 4.00 PM). In majority of the months atmospheric temperature reaches its peak value around 2.00 PM, except in the months of January, February, July and October, where it reaches by 3.00 PM. Atmospheric temperature fluctuates more in the second half of the year rather
than the first half, it is due to the fluctuation in incident solar radiation on the days of the experiment.

Wind velocity varies in the range of 1.4 - 3.8 m/s in the morning and then increases gradually to the level of 3.7 – 8.2 m/s between 2.00 - 3.00 PM. Then, it drops to the range of 2.3 - 7.8 m/s in the evening. Higher wind velocities are observed in the month of July 2009 among all the twelve months. In general wind velocities vary from 1.4 - 8.2 m/s, in the testing period from January to December 2009. Wind velocity varies in a drastic way in the months of June, July and August and the corresponding maximum wind velocities of 7.6 m/s, 8.2 m/s and 7.8 m/s are noticed in these months, because of the monsoon season in the region. Further, in the winter months of October, November and December, the variation in wind velocity is low and is almost constant between 9.00 – 11.00 AM on the days of the observation.

Figure 6.1  Incident solar radiation on the collector plane in WAS mode (January to June)
Figure 6.2 Incident solar radiation on the collector plane in WAS Mode (July to December)

Figure 6.3 Atmospheric temperature in WAS mode (January to June)
Figure 6.4 Atmospheric temperature in WAS mode (July to December)

Figure 6.5 Wind velocity in WAS mode (January to June)
Variation of mass flow rate of water across the collector during the twelve days (one day in each month) is shown in Figures 6.7 and 6.8. In the case of WAS mode, collector mass flow rate is a function of wind velocity. Higher the wind velocity, the wind mill produces more mechanical power which in turn runs the pump at higher speeds, thus more collector flow rate.

The maximum collector flow rates of 77 - 201 kg/h are observed around 2.00 PM and minimum flow rate of 47 - 101.59 kg/h is noticed in the evening (except July month). Whenever wind velocity is less than 3.00 m/s the mass flow rate across the collector is also minimum (less than 70 kg/h), in particular in the evenings. Also, higher flow rates are observed in the month of July due to higher wind velocity (around 6.0 – 8.2 m/s). Mass flow rate of above 170 kg/h is observed in the months of May, June, July and August, due to the existence of higher wind velocity of above 7.00 m/s in these months.

Apart from this, it is interesting to notice that the variation in collector mass flow rate in the months of October, November and December
between 9.00 – 11.00 AM is minimum, as that of wind velocity variation in that period. In general, the collector flow rate patterns obtained with WAS mode resembles the wind velocity variation pattern (Figure 6.5 and 6.6) of that particular month.

**Figure 6.7** Mass flow rate across the collector in WAS mode (January to June)

**Figure 6.8** Mass flow rate across the collector in WAS mode (July to December)
6.4 MEAN TANK-WATER TEMPERATURE

Initial temperature of water in the tank is kept close to 26.5 °C at 8.30 AM on all the days of experiment in order to make the comparisons easier. The water temperatures, measured at three different locations of the storage tank are averaged to obtain the mean water temperature and are plotted in Figures 6.9 and 6.10. A final tank-water temperature in the range of 54 - 64 °C is obtained in that particular test period. It is noticed that the mean tank-water temperature increases with time of the day due to heat collection by the collector. Maximum water temperature of 63.4 °C is noticed in the month of May 2009 which is the summer period in that region. From the graph, it is observed that because of lower heat gain rates in the evening hours, the mean tank water temperature rises to a very small value after 3.00 PM and the curve is almost flat after that period, on all the days of the experiment. Due to the variation in incident solar radiation levels, in the months of July to December, remarkable temperature difference is prevailing in the evening, even though the mean tank temperature in the morning 9.00 AM is almost same in these months.

Figure 6.9 Mean tank water temperature in WAS mode (Janurary to June)
Figure 6.10 Mean tank water temperature in WAS mode (July to December)

6.5 USEFUL HEAT GAIN RATE OF WATER

Useful heat gain by the water with time of the day is plotted in Figures 6.11 and 6.12. The variations are found to be in line with the variation of incident solar radiation. The higher heat gain rates are due to higher collector flow rate, which results in better heat collection and lower losses. In the case of WAS, the heat gain rates vary in the range of 374 - 750 W, 1150 - 1587 W and 40 - 341 W around 09.00 AM, 1.00 PM and 4.00 PM respectively. Highest heat collection rate of 1587 W is observed during July month because higher wind speed which produces higher collector flow rates (upto 201.67 kg/h). Variation of useful heat gain also follows the path of bell curve shape similar to incident solar radiation curve.

Also, the rate of increase in useful heat gain between 9.00 AM and 1.00 PM is more, in comparison with decrease in useful heat gain rate after 1.00 PM, in all the days of the experiment. Peak heat gain rates of above 1500 W is witnessed in the months of May, June, July and August, due to the
higher wind velocity in these months. Peak heat gain rates are in the range of 1150 – 1240 W in the months of January, February, March, October, November and December, and in the range of 1440 – 1450 W in April and September months.

Figure 6.11 Useful heat gained by water in WAS mode (January to June)

Figure 6.12 Useful heat gained by water in WAS mode (July to December)
6.6 INSTANTANEOUS EFFICIENCY OF THE SYSTEM

Instantaneous efficiency variation with time is shown in Figures 6.13 and 6.14 for all the twelve months of the year 2009.

![Figure 6.13 Instantaneous efficiency in WAS mode (January to June)](image)

Figure 6.13 Instantaneous efficiency in WAS mode (January to June)

![Figure 6.14 Instantaneous efficiency in WAS mode (July to December)](image)

Figure 6.14 Instantaneous efficiency in WAS mode (July to December)
It is observed that efficiencies are higher around the beginning of the day as the collector inlet water temperatures are lower, thus, less losses to the surrounding. From 10.00 AM onwards, the efficiency values decrease with time because of the increase in collector inlet fluid temperature. The increase in collector inlet fluid temperature increases mean collector plate temperature and thus increases heat loss from the system to the surrounding atmosphere. The efficiency values are 25 - 46 % around 9.00 - 10.00 AM, and then drop to 2.5 - 16.55 % around 4.00 PM. Among all the twelve months, June witnessed the maximum efficiency of 45.86 %. The efficiency drops at a faster rate after 3.00 PM and it is less than 10 % in the evening 4.00 PM in most of the months. It is due to the less heat gain of water in the collector side which leads to decrease in efficiency values. Also, from the graph it is noticed that the curve follows a similar path in majority of the months, except July, due to the maximum variation in wind velocity in that particular month.