DEVELOPMENT OF MODIFIED SOLAR WATER HEATING SYSTEM FOR EFFECTIVE UTILIZATION

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ABSTRACT

Human Society is blessed with abundance of free solar energy, eco-friendly clean hence it is globally accepted as one of the most promising alternative energy sources. The effective use of solar energy is hindered by the intermittent nature of its availability and effectiveness in domestic and industrial applications especially in water heating. The requirement plenty of hot water for domestic, commercial and industrial purposes is seen recently. Various resources i.e. coal, diesel, gas, electricity etc, are used to heat water are costly due to their limitations. In traditional solar water, due to some limitations all the users was not getting uniform temperature of water for use. To overcome above limitations a modified solar water heating arrangement with extra features developed to meet the following requirements 1) To deliver constant temperature output as per requirement of user 2) To work effectively in winter season also. A prototype of a modified solar water heating system was constructed and tested. In modified solar water heater, the user will receive uniform hot water temperature as per set value of temperature. In this modified solar water heater the heating storage tank (primary storage tank) and hot water storage stank are separated due to this modified solar water heaters are comparatively more efficient than traditional solar water in winter season also. This modified solar water heater can fulfill requirement of users at no cost effectively and efficiently.

Keywords *: Solar water heating system, Solar Energy, eco-friendly*

1. Introduction

1.1 Overview

Mother earth blessed with Solar Energy in abundance without cost. The solar radiation falls on the surface of the earth can be effectively utilized for the benefit of human society. One of the popular devices that harness the solar energy is solar hot water system (SHWS). The use of hot water for domestic purposes is a simple and effective way of utilizing solar energy. The setup and installation cost of solar water heating system is very high without operating cost. It is a natural solar thermal technology. In this system, incident solar radiation is converted into heat and transmitted to a transfer medium such as water [1].

Solar energy is one of the most capable of the alternative energy sources with rising demand with cost of fossil fuel for energy. Solar energy is considered an alternate and efficient source of renewable energy for various applications in both homes and industry. It is reported that heating water consumes approximately 20% of total energy consumption for an average family [2–5]. Solar water heaters provides hot water at cheapest easily available green energy to households as per requirement. It can operate at any climatic seasonal conditions and their performance various upon availability of solar energy at a geographical location [6–9].

1.2 Solar Water Heating System

A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber panel coated with selected coating transfers the hat to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and is delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to 80 C (Maximum) in a good sunny day. The total system with solar collector, storage tank and pipelines is called solar hot water system. Broadly, the solar water heating systems are of two categories. They are : closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from bore wells or from freezing temperatures in the cold regions. In the other type, either thermosyphon or forced circulation system, the water in the system is open to the atmosphere at one point or other. The thermosyphon systems are simple and relatively inexpensive. They are suitable

for domestic and small institutional systems, provided the water is treated and potable in quality. The forced circulation systems employ electrical pumps to circulate the water through collectors and storage tanks.The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, annual solar radiation, etc. The SHW systems are economical, pollution free and easy for operation in warm countries like ours. Based on the collector system, solar water heaters can be of two types [E1].

1.2.1 Flat Plate Collectors (FPC) based Solar Water Heaters

The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water. There are 60 BIS approved manufacturers of Solar Flat Plate Collectors [E1].

1.2.2 Evacuated Tube Collectors (ETC) based Solar Water Heaters

Evacuated Tube Collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube. Solar water heating is now a mature technology. Wide spread utilization of solar water heaters can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial and institutional establishments. Internationally the market for solar water heaters has expanded significantly during the last decade [E1].

2. Review of Literature

Presently, alternative energy resources are being harnessed for various domestic as well as industrial applications such as power generation, air conditioning, space heating, and domestic hot water system. Photovoltaic thermal technology (PVT) refers to the solar thermal collectors that use PV cells as an integral part of the absorber plate. This kind of system generates both thermal and electrical energy simultaneously [10]. In India solar water heaters were reported to provide 100 L of hot water at an average temperature of 50–70∘C, which can be retained to 40–60∘C until used next day morning [11]. The spiral flow absorber collector at temperature of 55°C achieved the best mass flow rate at 0.011 kg/sec and generated combined PVT efficiency of 64%, with 11% of electrical efficiency and maximum power of 25.35 W. Al_2O_3 and MWCNT water nanofluids have significant effect on the efficiency of FPSC (flat plate solar collector) experimentally. The results shows that use of Al_2O_3 and MWCNT water nanofluids in comparison with water as working fluid increased the efficiency up to 28.3% and 35%, respectively [12]. Samara Sadrin et al [E2] in his study present the alternative method of solar water heating system. This automated system would allow the user to get hot water from the solar water heater as long as the solar water heater can supply hot water above a set temperature. If the solar water heater is unable to supply water above the set temperature, then only will the electric water heater come into action. It is efficient because our controller ensures that the solar water heater is used to supply hot water 80% of the time, and the rest 20% will be supplied by the electric water heater. It is cheap because, our system runs on solar energy which is abundant and free. It uses very small amount of electricity and therefore, reduces the expenses for the user. P. Rhushi Prasad et al [13] present experiment analysis of flat plate collector and comparison of performance with tracking collector. A flat plate water heater, which is commercially available with a capacity of 100 liters/day is instrumented and developed into a test-rig to conduct the experimental work. Experiments were conducted for a week during which the atmospheric conditions were almost uniform and data was collected both for fixed and tracked conditions of the flat plate collector. The results show that there is an average increase of 40C in the outlet temperature. The efficiency of both the conditions was calculated and the comparison shows that there is an increase of about 21% in the percentage of efficiency. P. Sivakumar et al [14] discuss

improving the performance of a flat plate solar energy collector by changing the design parameters of the number of riser tubes and the arrangement of riser tubes in zig-zag pattern from the existing flat plat collector system. Experiments were conducted using copper tube in header and riser with different dimensions. The performance shows that the efficiency is 59.09% when increasing the number of riser tubes and its 62.90% in the zig-zag arrangement (Z- Configuration) of the riser tube. The maximum collector efficiency during the day of experiment at any particular time considered is obtained in case 3 experiment using zig-zag arrangement. Mustafa AKTAß et al [15] describe experimental analysis of optimum fin size, which can be used in heat exchanger in solar energy systems, has been performed. For this purpose, two systems, one of which is classic and the other finned, were designed and manufactured. According to the experimental tests, which lasted for six days, the system with a fin is 7% more efficient than the classical system. Therefore, it has been concluded that it is useful to use fins in solar energy systems with a suitable sizing.

2.1 Gap Identification

In India, the solar water heating system is mostly used for bathing purpose. The bath timing for an Indian family varies from 7 to 11 am. It is observed that the temperature of hot water gradually decreases as the consumption of water increases; this is because as the hot water delivered through outlet valve, the fresh cold water enters through inlet valve. Thus the overall temperature of water stored in storage tank decreases as the consumption of water stored in storage tank increases. The initial users get very hot water for use and later on the next users get lukewarm water. As the solar water heater works on the principle of water siphon effect, the user cannot get the constant temperature hot water for use. During the rainy season, the average solar radiation falling is comparatively weaker, which affects heating effect of water stored in tank. Due to above limitations, the solar water heaters are less preferred compared to other heater systems such as electric heaters, fossil fuels etc.

The aim of the present study is to develop a modified solar water heating arrangement with extra features so that society should use solar water heating system effectively.

The objectives of this study is

1) To develop a modified solar water heating arrangement with extra features.
2) To deliver constant temperature output as per requirement of user.
3) To work effectively in winter season also.

3. Materials and Methodology

3.1. Materials and Prototype Development.

The proposed prototype model solar water system consists of pipe network, storage tank, evacuated solar tube, temperature sensor, solenoid valve, microcontroller unit, water level sensor, hot water storage tank etc. Figure 1 presents a complete proposed model of modified solar water heating systems. The difference between traditional evacuated tube solar water heater system and proposed mode is microcontroller unit is fixed in this proposed system with mounting of temperature sensor, water level sensor and solenoid valve.

3.2 Experimental Setup and Process Description.

In the proposed modified solar water heater system as shown in figure 1, the cold water storage tank (1) is placed on stand (1) which is at a certain height above the evacuated solar water heater. The outlet of cold water storage tank (3) is connected as inlet water supply valve (4) for solar water heater system. The evacuated tube solar water heater system is installed on stand (5) at a fixed inclination so that the evacuated tube (6) exposed to proper sun radiation. The rated water solar water heater storage tank is split into two tanks i.e. one is solar water heater tank (7) and other is hot water storage tank (12). A water temperature sensor (8) is fixed in solar water heater tank and on outlet pipe of solar water heater tank (7) a solenoid valve (9) is provided for regulating the hot water flow to the hot water storage tank. The water level sensor (11) is also fixed in hot water storage tank (12). The electrical connections of water level sensor, temperature sensor and solenoid valve is provided to the microcontroller circuit (10). The hot water outlet valve (13) is provided to the hot water storage tank, which is fixed on stand (14). The experimental set is shown in figure 2.

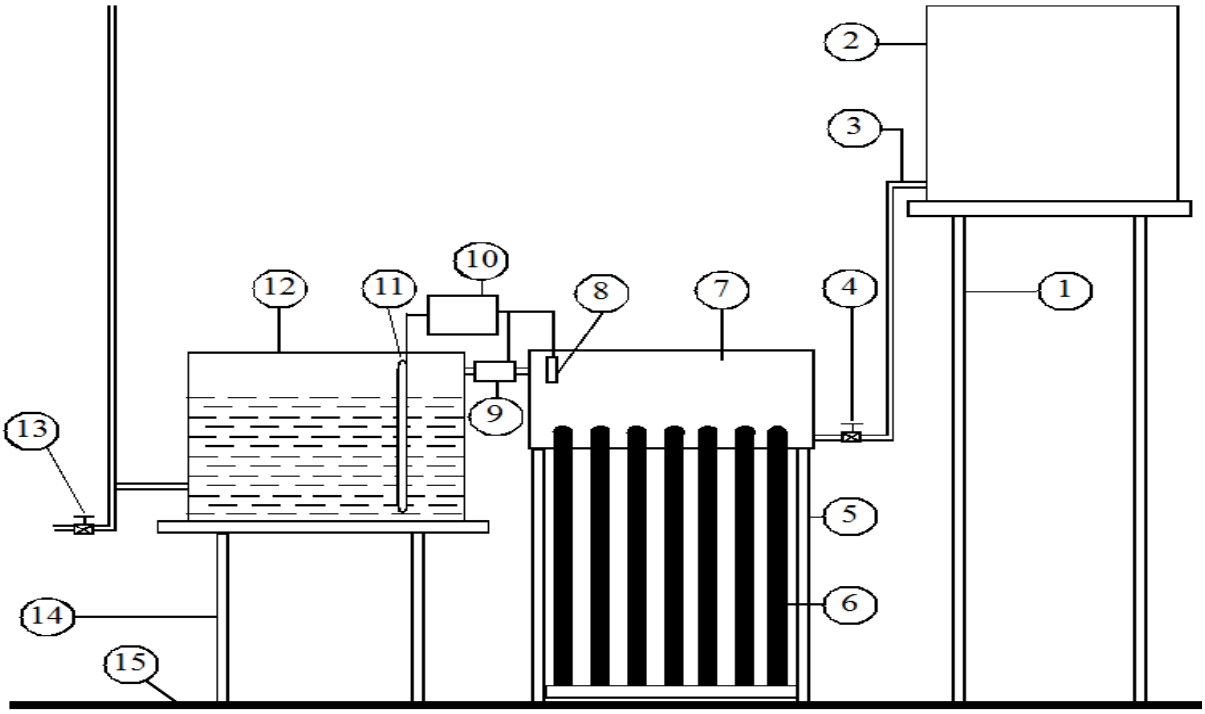

Fig.1 : Proposed modified solar water heating system

(1 -Stand for cold water storage tank,2- Cold water storage tank, 3 - Cold water outlet pipe,4- Inlet valve for solar water heater tank, 5- Solar water heater stand, 6 -Evacuated solar tubes,7- Solar water heater storage tank (Primary storage tank), 8 -Temperature sensor,9-Solenoid valve, 10 -Microcontroller unit, 11 -Water level sensor,12 -Hot water storage tank (Secondary storage tank), 13-Hot water outgoing valve,14 -Stand of hot water storage tank, 15 - Ground level.)

Fig.2 : Prototype of modified solar water heating system

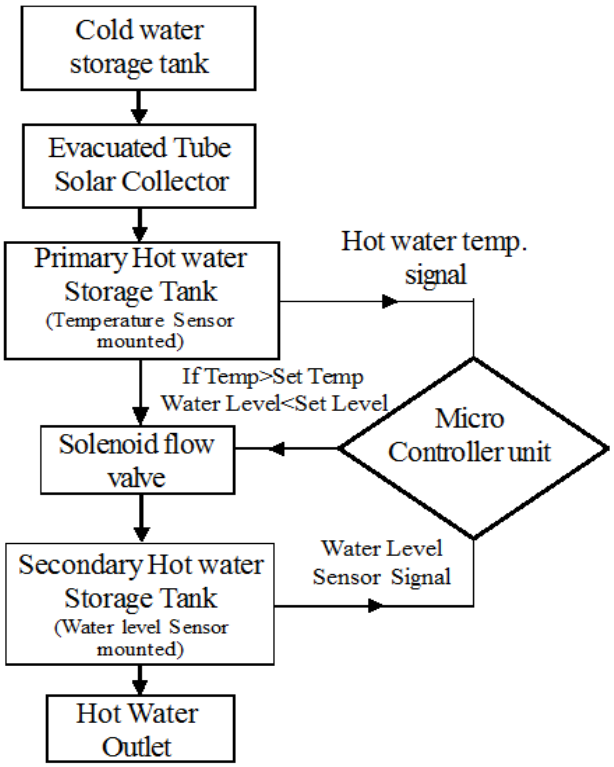

Fig.2 : Flow diagram working of modified solar water heater system

In the proposed modified solar water heater works in above manner shown in figure 3, the water from the cold water storage tank enters through the inlet valve (4) to evacuated solar water heater storage tank. The evacuated solar tube provides thermal energy to the water in storage tank and the hot water is moved towards the top of storage tank due to water siphon effect. The temperature range of hot water to be required is set in the microcontroller unit as well as the ON/OFF function of solenoid valve is set according to temperature range (i.e. maximum temperature at which the valve open and minimum temperature at which the valve closes). As the water of storage tanks attains required temperature level, the solenoid valve opens and the hot water is transferred from solar water heater tank to the hot water storage tank through pipe on which solenoid valve is mounted. The solenoid valve will close when the temperature of water storage tank falls below backlash temperature (Backlash temperature is the temperature range within which the solenoid valve open or close). The hot water flows through solenoid valve is collected in well insulated hot water storage tank, where water level sensor is fixed. When the hot water storage tank is full, the water level sensor senses the level of water and it will transmit signal to the microcontroller unit and the microcontroller unit cut the supply of solenoid valve, so that no further water should be entered in the hot water storage tank. As the level of water decreases the microcontroller unit starts the supply to the solenoid valve and hence water will flow to the hot water storage tank. Thus the user will get constant temperature water for consumption.

4. Conclusion

The purpose of this work was to develop a modified solar water heating system for effective utilization in all seasons. A prototype of a modified solar water heating system was constructed and tested. In modified solar water heater, the user will receive uniform hot water temperature as per set value of temperature. The overall working of this prototype efficient and effective. Limitation of natural resources, the cost of gases and electricity is increasing rapidly. As a result, it would not be possible to use hot water for all types of domestic work by using gas or electricity. In traditional solar water heating system, there is limitation of supplying uniform hot temperature water. Due to this limitation most of domestic users shifted to electric geysers or solar water heater with

electric water heater. In this study, we have tried to modify traditional evacuated tube solar water heater with additional microcontroller circuit for effective utilization of solar water heater which can supply constant temperature water for various applications. In this modified solar water heater the heating storage tank (primary storage tank) and hot water storage stank are separated due to this modified solar water heaters are comparatively more efficient than traditional solar water in winter season also. This modified solar water heater can fulfill requirement of users at no cost efficiently without using gas or electricity. Future recommendation will focus on future testing and exploration of financing options.

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