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Integration of ETC Solar Water Heater with Heat Pump for Energy Efficiency

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Abstract: *There is a large demand of electrical power for domestic application. Water heating is one of the domestic application require electrical power or fossil fuel. The demand is increasing continuously and results into energy crises, depletion of fossil fuels and damage to the environment. In response to the present situation, people are researching different ways to conserve energy, reduce the cost of electricity and make alternative energy solutions available. Solar energy is an unlimited source of non-conventional energy for water heating application but its weather dependent. In this paper energy efficiency of integration of Evacuated tube collector (ETC) solar water heater with heat pump is discussed. Heat pump is acting as backup system which will bring the hot water to the temperature required when there is not enough sunlight to do so (mostly in winter).The outlet temperature of hot water is closely controlled through temperature sensors. It is observed that ETC solar water heater integrated with heat pump is energy efficient option available and having energy consumption of 4.05 kWh per day. The heat pump is on for 3 hours in monsoon and for 5 hours in winter during on an average two months in a year.*

Keywords: *COP; ETC Solar water heater; Heat Pump.*

1. INTRODUCTION

Water heating is a major component of residential energy use, often ranking as the second largest energy use in the home and accounting for 14-25% of overall household energy consumption [1]. A home resident depends on a reliable and sufficient supply of hot water for multiple uses in the home. They are also increasingly aware of the energy and carbon emission implications of different hot water systems. Rising energy prices and the other economic pressures have created more interest in energy efficient hot water systems which reduce monthly utility bills while still providing reliability and comfort. Solar energy is playing very significant role in replacing conventional expensive and polluting fuels to produce hot water. In 2010, Renewable Energy Policy Network has reported that about 70 million houses are now using solar water heating systems worldwide [2]. Domestic solar water heating is established technology used to reduce the energy demand for providing domestic hot water for various applications [3-6]. Solar collectors alone cannot provide all the hot water for a household's needs throughout the year. They are normally installed in conjunction with a conventional heating system, the back-up heater. Those conventional back-up heaters are usually simple but not desirable in the view of energy utilization efficiency. Heat pump water heating systems are energy efficient compared to conventional water heaters like electric geyser and gas geyser [7]. In the past years many systems in which combination of solar water heater with back-up heater have been developed and introduced to the market for both domestic hot water and space heating. On the basis of literature review and available systems in the market Elimar Frank et al. studied the different approaches of combined solar and heat pump systems [8]. The performance analysis of solar assisted heat pumps for water heating is studied by Luca et al [9].

In this paper energy efficiency of ETC solar water heater integrated with heat pump is measured thought year. Energy efficient Heat pump is used as back-up system with ETC solar water heater. ETC Solar water heater integrated with heat pump operated for producing hot water at 60 ^{0} C and work time duration of heat pump is measured . It is observed that heat pump is on for 3 hours in monsoon and for 5 hours in winter during on an average two months in a year. It is observed that consumption of heat pump to produce hot water at 60 ^{0}C is 4.05 kWh.

2. EXPERIMENTATION

Evacuated tube collectors integrated with heat pump is fabricated for 300 people of capacity 5000 Lpd. Solar collectors' heat up the water in solar tank. When the temperature in the tank is high enough, the energy can be used to heat up the water and heat pump is blocked, enabling all the energy for heating to be provided by the sun. Integrated hot water system of evacuated tube collectors and heat pump is shown in Figure 1. It is

combination of two clean renewable energy sources and gets the best of it. Neither a heat pump nor a solar energy system uses any combustion process for heating water. It simply uses the heat that already exists in the air and puts it to use to heat water. Secondly, in comparison with other heating systems, the amount of electricity needed is low. That's because electricity is not the main energy source means lower emissions, it's only needed to run the heat pump and enable the heat extraction process. It consists of main water tank which supplies water to a solar system. Solar tank is used to store a hot water at day time and pass it to hot water tank. Hot water tank collects hot water and supply to application at desired temperature. Water from solar tank is circulated in evacuated tubes. The two temperature sensors are used at the inlet and outlet of solar collector tube system. Solar system is working at day time only when there is availability of sunlight. The water from main tank is heated in ETC solar tubes, which are mounted on solar panel and heated water is circulated throughout the system consisting of seven panels as forced circulation by using pump. Parallel arrangement of solar tubes is used so that water passes through each & every tube and temperature of water increases gradually. The heat pump is used in parallel with solar system integrated with PLC in order to get required hot water temperature. The heat pump acts as backup system only when solar intensity is not up to the requirement for solar water heaters.

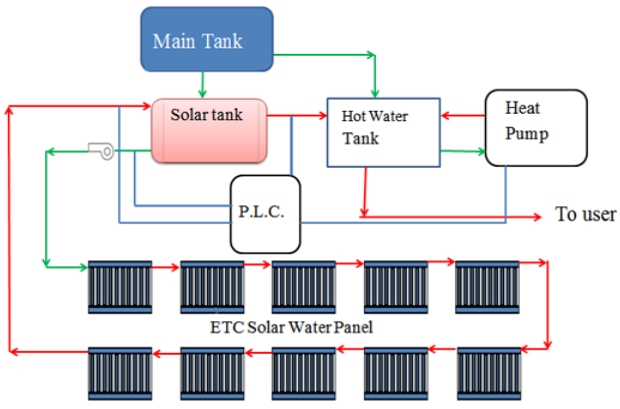

Figure 1: *Evacuated tube collector integrated with heat pump*

Red line shows hot water flow, green line indicates cold water flow and blue line shows sensor wire. The programmable logical controller (PLC) is used which controls system automatically as it was programmed. PLC consists of temperature sensors, time sensors and switching mode to switch from one condition to another condition. The two temperature sensors are incorporated at input and output of solar system whose function is to check whether the temperature difference that has been already set is achieved or not. The water flows through the system only if temperature difference is achieved. The system is in place for producing hot water in the hot water tank at 60°C. The solar system will work throughout the day raising the temperature of hot water. If by the working of solar water heater temperature is not reached to 60°C then heat pump will raise the remainder temperature to the desired level. The temperature in hot water tank is measured by using temperature sensor. When the required temperature is achieved in hot water tank, it is supplied to the user. Both tanks are insulated with aluminum cladding to reduce heat losses to the surroundings.

3. RESULT AND ANALYSIS

With the approach of integration between solar collector and heat pump, it is possible to produce hot water throughout year at less operating cost. The hot water is used for bath purpose in boy's hostel of our institute. In this case various types of energy and its consumption (heating effect) are discussed for heating water. In our boy's hostel intake capacity of 300 students require hot water 4500 Lpd by considering 15 liters per student per day. Including various losses and buffer stock, the capacity of hot water system is considered as 5000 Lpd. Energy required to produce hot water at 60^0C from water at 25^0C is 203.53 kWh. The operating cost comparison of various hot water heaters like electric geyser, gas geyser, and heat pump is carried out on the basis of energy requirement to produce hot water at 60^0C.

3.1. Electric Water Heater

The efficiency of electric heater is considered as 80% which require electricity 203.53 kWh for producing required hot water at 60^0C.

Electricity charge for commercial purpose as per MSEB is = Rs. 8.38 / unit

Electricity Charges per day = 203.53 x 8.38

= Rs.1705.58/-

Electricity Charges per year = 365 x1705.58

= Rs 6,22,536.21/-

3.2. Gas Geyser (LPG)

Calorific value of LPG = 11900 kcal / kg

For sake of simplicity converting above value in kJ/ kg,

Calorific value of LPG = 11900 x 4.187= 49825.3 kJ/kg

We know that, Energy required for heating of water / day = 732725kJ

Mass of LPG required / day = 14.70 kg

Mass of LPG required / year = 14.70x365= 5365.5 kg

Number of gas cylinders required / year =282.39

Total cost for water heating by gas geyser

= No. of cylinders required x cost of one cylinder

= 282 x1900

= Rs 5,35,800 /-

3.3. Heat Pump

Specifications:

Rated power = 3.8 kW

Water O/P = 425 L/hr

Range of COP for heat pump = 2.5 to 5. In this case it is taken as 3.5, so that power input required is 58.15 kWh.

Electricity required for heating of water by heat pump = 60 unit/day

Electricity Charges / day = 60 x 8.38

= Rs 502.8 /-

Electricity Charges / year = 365 x502.8

= Rs. 1, 83,522 /-

3.4. ETC Solar Water Heater integrated with Heat Pump

There is no need to operate heat pump during summer season since there will be enough sunshine in that period. So, the solar water heater is sufficient to meet the requirement. But for monsoon and winter season, sunlight is not sufficient for the working of solar water heater.

It is observed that heat pump is on for 3 hours in monsoon and for 5 hours in winter during on an average two months in a year.

Total No. of working hours for heat pump can be given by,

(5x60) + (3x60) = 300+180 = 480 hours

Electricity Consumption for heat pump in one year

= Rated power x working hr.

= 3.08 kw X 480 hr.

= 1478.4 kwh

Electricity Charges / year = 1478.4 X 8.38

= Rs. 12388.992/-

The summary of operating cost of various water heating methods is shown in Table 1.

Table 1: *Summary of operating cost of 5000 Lpd water heating methods*

Sr. No.	Water heating method	Electricity (unit) or gas (kg) consumption/ day	Per liter cost (paisa)	Yearly Operating Cost (Rs.)
1.	Electric Heater	203.53kWh	34.11	6,22,536.21
2.	Gas Geyser	14.70kg	29.4	5,35,800
3.	Heat Pump	60kWh	10.05	1, 83,522
4.	ETC integrated with Heat Pump	4.05 kWh	0.67	12,388.992

4. CONCLUSION

Evacuated tube collector water heater integrated with heat pump is developed for improving energy efficiency on the basis of integration approach. It's performance is found for throughout year, which indicates ETC is unable to provide hot water at required temperature for two months in a year. During insufficient sunshine energy efficient heat pump provides hot water at desired temperature. The combined hot water system operate with less operating cost and require less electricity which indirectly avoid burning of fossil fuels and provide environment eco-friendly solution.

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