

Passive generation of electrical energy from a solar water heater

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Abstract - This article aims to propose a system design based on a solar water heater system and its details for electricity production throughout the year. To date, very few attempts have been made to generate continuous electrical energy from low grade solar water heater systems. The design is based on evacuated tube solar collector that acts as the input for solar energy, and supplies this energy to the thermoelectric generator modules, which then in turn give electrical energy as their output. Even when the solar water heater is generating electricity, the arrangement of the components is set such that hot water, the primary output of the solar water heater, is available on demand to the end user.

Key Words: Solar; thermoelectric; solar water heater; thermosiphon; electricity generation

1. INTRODUCTION

The existing Solar water heater (SWH) systems are typically used heavily for only about 110 days in a year (90 days of winter and 10 days before winter sets in and 10 days after it ends). Even if it is used year round, a solar water heater is capable of using the sun's heat to generate far more hot water than is used. The current design of the solar water heater has no measures in place to utilize the hot water when it is simply stored in the tank. Therefore, a large amount of the energy generation potential of the water heater goes to waste. It is possible to generate electricity from the heated water by coupling a thermoelectric generator to the solar water heating system, thus increasing its utilization and prompting faster return of investment.

2. MAIN COMPONENTS IN THE PROPOSED DESIGN

2.1 Evacuated tube type solar water heater - Vacuum tubes are the main component in this version of a solar water heater, which collects and absorbs solar energy. The vacuum tube is an assembly of two concentric, borosilicate glass tubes. It also may be an arrangement of conductive copper pipe around which an evacuated borosilicate glass tube is present.

Vacuum between the gap of two glass tubes acts as the best insulation to minimize the heat loss from inner tube. The black coating on the inner tube absorbs the solar energy and transfers it to the water. The water on upper side of vacuum tube becomes hot and thus lighter, so it starts moving upwards to the storage tank. At the same time cold water, which is heavy, comes downward from the tank and is stored at the bottom. This is a continuous cycle.



Fig – 1: A commercially available evacuated tube collector based solar water heater

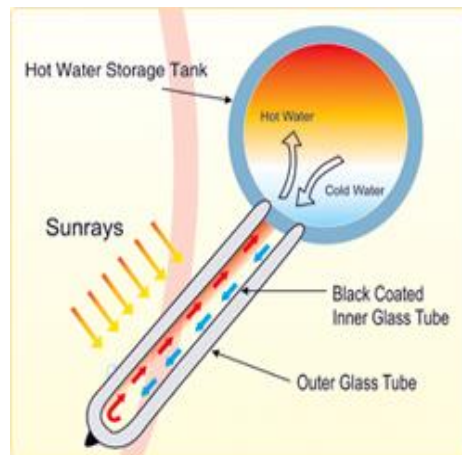


Fig – 2: A visual representation of the working of the above mentioned solar water heater

2.2 Thermoelectric generator - It is a solid state device that converts heat flux (temperature differences) directly into electrical energy. It works on the Seebeck effect to convert heat into electricity. When two dissimilar metals are brought in contact with each other, such that the junctions where the metals touch are at different temperatures, a voltage is developed between the junctions, proportional to the difference in the temperatures. A current is generated as a result. This is called the Seebeck effect.

In the proposed system design, with which aforementioned objectives will be achieved, a temperature difference (which is necessary for the TEG in order to develop a voltage and generate current) will be present due to the hot water flowing over one side of the TEG, while the other side is exposed to atmosphere, which is at a comparatively cooler temperature. As a result, the thermoelectric generator will be able to generate electricity

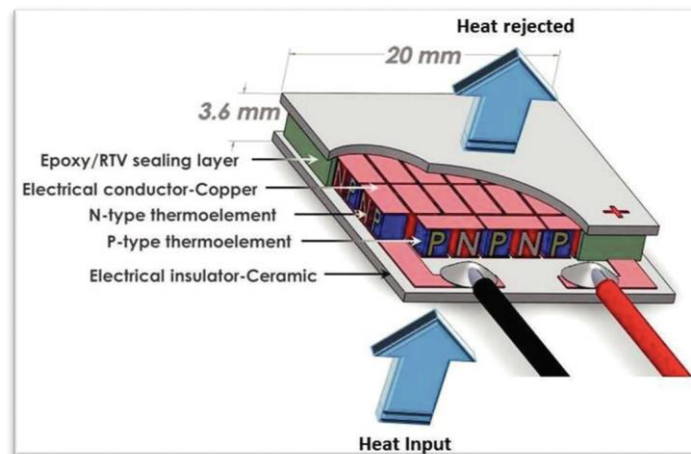


Fig – 3: A visual representation of the cross-section of a commercially available TEG module

3. SYSTEM DESIGN AND WORKING

This design is based on the thermosiphon effect, in which the difference in densities of water at different temperature causes hotter water to move upward, owing to its lowered density. This allows us to move our working fluid without using an energy consuming device like a pump in order to accomplish the same.

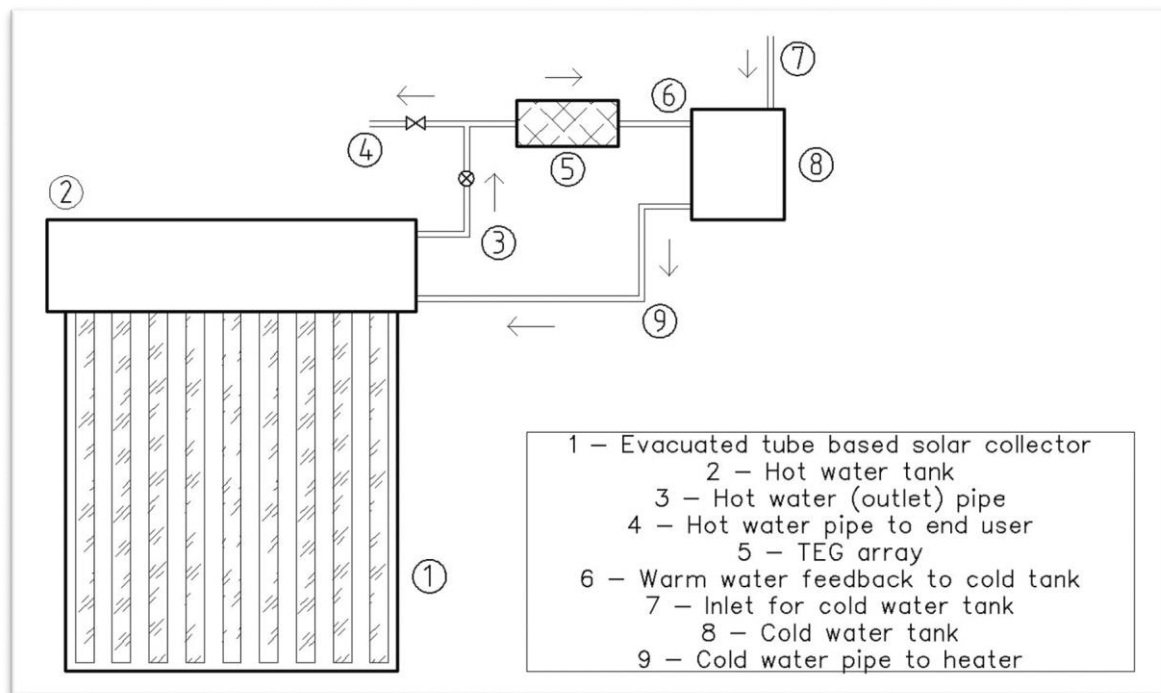


Fig - 4: A representation of the aforementioned system

Cold water from the cold water tank flows into the solar water heater due to a lower head at the heater inlet, and water's density being greater than air at atmospheric pressure. This cold water moves downward again into the evacuated tubes. These tubes collect and trap the sun's energy, which is in turn absorbed by the water flowing in them. As the water absorbs energy, its temperature increases, and consequently, its density is lowered. Due to the difference in densities of water at inlet of the evacuated tube, and of water that has become hot inside the tube, thermosiphon effect comes into play, and the hot water moves upward. The quantity of water that moves up into the insulated hot water tank is replaced by the incoming cold water.

An outlet provided at the top section of the insulated hot water tank (as the top half is where the hot water accumulates) allows the hot water to continue its upward movement, which leads it to a T junction, one side leading to the thermoelectric generator modules, and the other working as the hot water supply to the user. Since the water heater's primary purpose is hot water supply to the user, this split in the pipeline allows hot water to flow to the user's end when the tap valve is opened by the user, rather than the warmer water whose energy has been given up to the thermoelectric generators for electricity generation purpose.

The hot water that flows over the thermoelectric generators provides energy to their hot junction. The cold junction is the side exposed to atmosphere, which is at a lower temperature. Thus, a temperature difference is created, as a result of which the thermoelectric generators can produce electricity. This water, which is at a lower temperature than when it was output from the water heater, is now fed back into the cold water tank.

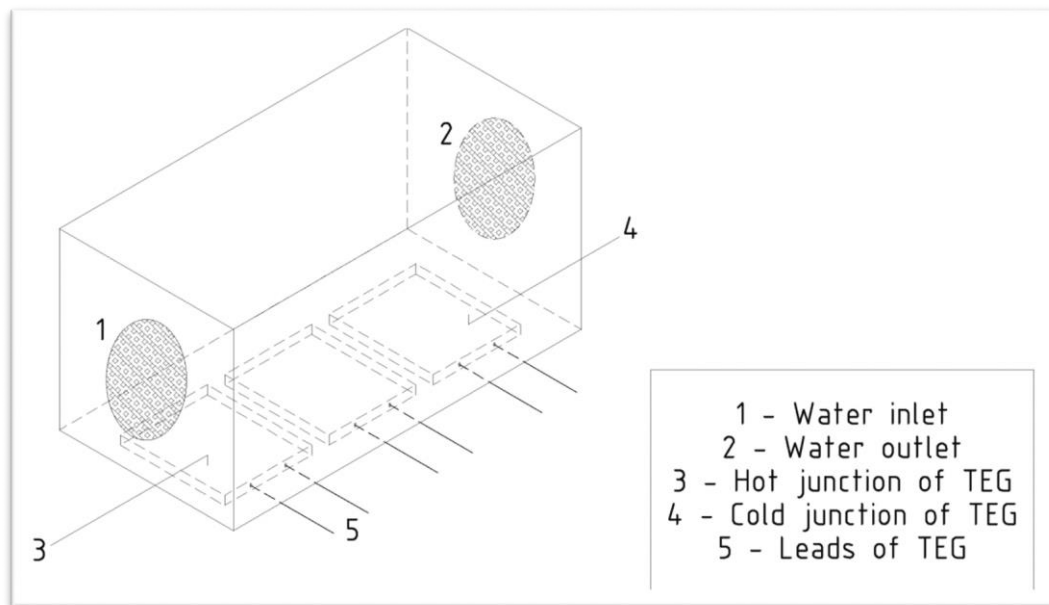


Fig - 5: A representation of the thermoelectric generator setup to harness the output of the solar water heater

This feedback loop results in no water being wasted, and all of it being used for productive purposes. Further, mixing warm and cold water also causes the overall temperature of water in the cold water tank to be increased slightly, which, when cycled back into the water heater to be heated, reaches a higher temperature than it would reach under normal circumstances. This is a cyclic process, and continues even at night, by using the heat trapped in the glass jacket of the evacuated tubes to heat water.

4. CONCLUSION

An original system design consisting of evacuated tube collector based solar water heater and thermoelectric generators was created. This was done in lieu of the current working conditions of standard, commercial evacuated tube collector based solar water heaters, and to harness their latent work potential. A design of a setup of thermoelectric generators to suit this system was also presented. In doing so, we have a design that is capable of extracting additional work output from a device that hitherto had limited usage. Further, it is capable of 24 hour working, giving it a significant edge over conventional photovoltaic systems. It requires little to no maintenance due to the absence of frictional forces and vibrations. The only case of breakdown or improper functioning possible is if the insulation of the hot water tank has a rupture or a leak, which can cause scaling, reducing the temperature of hot water obtained due to greater rates of heat loss. It also retains another one of the primary advantages of a solar water heating system, which is its long life.

In addition to these characteristics, it generates energy on the side, during its downtime, thus giving a faster return on investment.

The design has scope for future research, experimentation and testing in regards to the rate of heat transfer on the cold junction of the thermoelectric generator module, which can permit a greater temperature difference and hence, give even higher output. In scenarios where thermosiphon effect cannot drive hot water to the potential head at which the thermoelectric generator array and the feedback pipe to the cold water tank, alternate techniques to accomplish the same can also be explored. Depending upon the size of the water heating system, and the cumulative output provided by them, the applications of the obtained energy can also be far and wide.

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