IJEW 国际工程期刊 International Journal of Engineering Works انجینرنگ کاموں کا بین الاقوامی جرنل

International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 8, Issue 07, PP. 180-184, July 2021
https://www.ijew.io/
https://doi.org/10.34259/ijew.21.807180184
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Effect of Local Seasonal Temperature Variation on Energy Efficiency of Water Evaporation using Peltier Module

Imtiaz Ahmad
PG Research Student, Department of Mechanical Engineering, UET Peshawar KP Pakistan
imtiazahamdmkd@gmail.com

Received: 11 June, Revised: 29 June, Accepted: 05 July

Abstract— A residential surface water tank is normally exposed to ambient conditions. Evaporation of water from such a source, using a Peltier device is expected to results in variation of energy efficiency for a system due to variation of ambient temperature. In this research work local conditions of city of Peshawar in Khyber Pakhtunkhwa province of Pakistan are considered. A MATLAB Simulation was performed to find out the seasonal energy efficiency variation for Peltier based evaporation. The results show that there is significant variation of energy of evaporation process due to seasonal variation ambient conditions.

Keywords— Ambient conditions, Peltier module, Simulation, MATLAB Simulink.

I. Introduction

Water is the most important component of human's life. It is used for different purposes ranging from drinking to agriculture and industrial use. Ground water is the water present beneath the earth. [1]. The problem with ground water it that it contains some unwanted impurities. The type and concentration of impurities found in ground water depends on geological material through which water flows. Some of the common impurities are magnesium, calcium, chloride, arsenate nitrate and iron [2]. Other industries and agriculture impurities are also found in water such as mercury, copper chromium lead etc.[3]. According to world health organization (WHO) standard, water containing impurities less than 1000mg/L is fit for drinking [4]. Due to global warming and excessive use , the scarcity of Water is increasing day by day, by the year 2025, 1800 million of people will not have access to clean water, and almost two-third of population could be under severe stress condition[4], [5]. The reasons behind the scarcity of water is overpopulation, industrial waste product and pollution [6]. Sometimes water is available but it is not fit for use, such water is called brackish water. Brackish water is water contains impurities [7]. Hazardous impurities are removed by different processes called desalination of water to make it fit for use. For this purpose, many different methods, one of the cheapest method is evaporation of water. In evaporation of water the brackish ground water is exposed to heat allowing molecules to form vapors and impurities are remained at the bottom of container. By evaporation of water, unwanted impurities are removed from brackish ground water.

II. Literature Review

Water scarcity threat is increasing in south Asia and especially in Pakistan. Pakistan is facing many serious challenges in near future, out of which one is water scarcity. It is estimated that Pakistan will run out of water till 2025[8]. To overcome this challenge, many solutions are reported, out of which one is Thermal distillation which involves evaporation of water[9], [10]. Distilled water is the purest form of water and distilled water has some good effects on human's health[11]. The evaporation of water is a function of pressure inside the chamber. Decreasing the pressure inside the chamber creates vacuum. Due to vacuum water evaporates at low temperature and hence low energy input is required[12]. Vacuum desalination is a viable method for distillation of brackish / sea water. The cost of decreasing pressure is lower than the cost of heating water at normal temperature [13]. The natural vacuum desalination system works at low pressure which is achieved by gravity. Evaporation at low energy input is required which means low temperature input is utilized. Waste heat or renewable energy is utilized [14]. The performance of natural vacuum desalination system is affected by evaporator temperature and ambient temperature. Impurity in brackish water also plays a vital role in evaporation [15]. The local Ambient plays an important role in evaporation and condensation. Local ambient temperature is a function of declination angle, day length, Latitude and day of year counted from January 1st, ambient temperature is not same throughout day and night, and it is changing[16]. Evaporation of water requires input heat (heating) and condensation of evaporated vapors require cooling. For this purpose a thermoelectric device called Peltier device is one of the best suited solution. Peltier module is a device when potential difference applies, it creates temperature difference. The Peltier module has two junction, when potential difference is applied, one junction becomes hot while the other becomes cold. The hot side evolves heat while the cold side absorbs heat. The hot side is used to heat water evaporator and cold side is used to extract heat from hot vapors in condensation chamber. It works as heat pump [17]–[19]. Peltier module works better at low hot side temperature and low temperature difference between hot and cold side [20]. Productivity of Peltier module is important. Madhhachi [21] reported that the productivity of Peltier module is 91%, out of total input electric power, 52% of electric energy is used for electric energy is used for evaporation and 39% of electric energy is used for condensation.

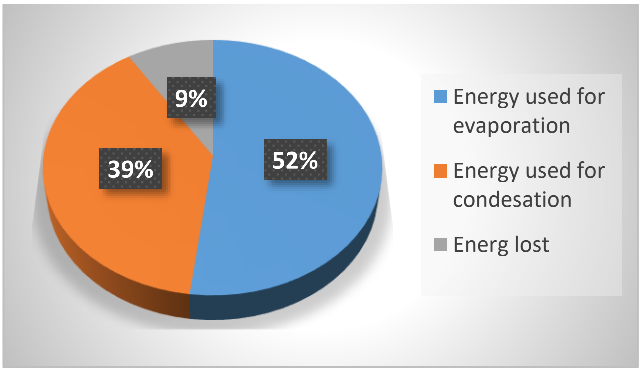

Figure 1. Productivity of Peltier module reported by Madhhachi [21].

III. METHODOLOGY

Peltier based evaporation is modeled and simulated in MATLAB Simulink taking into account the local ambient temperature. MATLAB Simulink is a simulation software consists of block which is used to solve dynamic equation. It is used to study the performance of different system using graphs. It is easy to use and user friendly. MATLAB Simulink has wide spread libraries. As Peltier module works like heat Pump. It creates temperature difference when voltage is applied across the Peltier module. One junction evolves heat and becomes hot while the other junction becomes cold and the other becomes cold. The hot junction of module evaporates water. The schematic diagram of working of Peltier module is given below in figure 2.

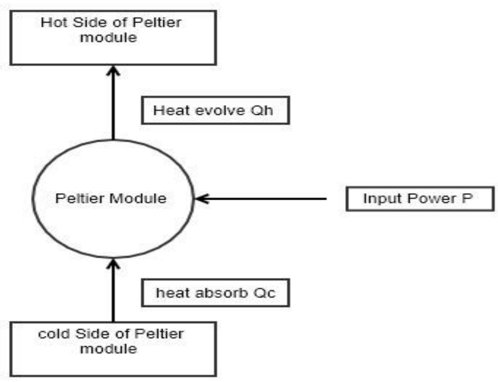

Figure 2 Schematic diagram of Peltier module.

The heat released by hot side and cold side of the Peltier module is given by equation [22].

$$Q_h = ST_h I + 0.5RI^2 - K\Delta T \tag{1}$$

$$Q_c = ST_c I - 0.5RI^2 - K\Delta T \tag{2}$$

$$COP_H = \frac{Q_h}{P_{in}} \tag{3}$$

Where S is seebeck coefficient, I is current through module, R is resistance of Peltier module, K is thermal conductivity of module, T_h is temperature of hot and T_c is temperature of cold side , and ΔT is temperature difference between hot and cold side.. The above equations are used to simulate the system in MATLAB Simulink. The hot side the Peltier module is used to heats up water in the evaporation chamber and the cold side of the Peltier module is used cools down hot vapors. Peltier module in the current system transfers heat from the cold side of the Peltier module to the hot side of the Peltier module. The modeled is developed in MATLAB Simulink and run few time. Blocks are created and each block represents each component of model.

TABLE I. VALUES OF DIFFERENT PARAMETERS OF PELTIER MODULE

Seebeck coefficient (S)	0.0196 V/K
Thermal Conductance (K)	0.96 W/K
Resistance (R)	0.152 Ω

The local ambient temperature also plays important role in evaporation of water. As when water evaporates, the temperature of water is greater than ambient temperature therefore some useful heat is loss to surrounding due to temperature difference between water and ambient. As reported in the literature that ambient temperature is changing hour by hour. Ambient temperature depends on declination angle, latitude of place, day length and day of year counted from January 1st. A plot of temperature variation of May 27 in Peshawar is given in figure 3 [23].

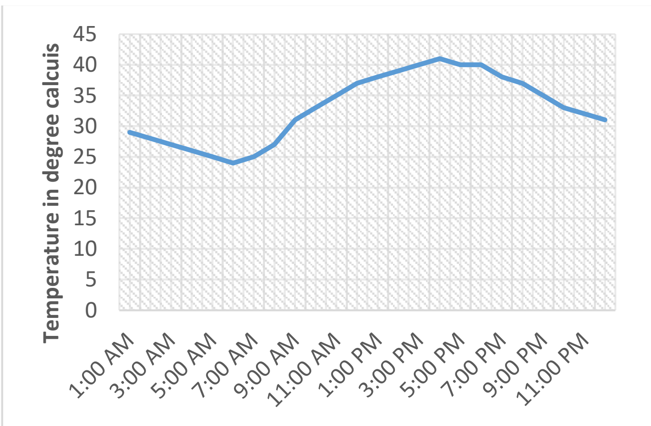

Figure 3. Temperature variation in Peshawar on May 27.

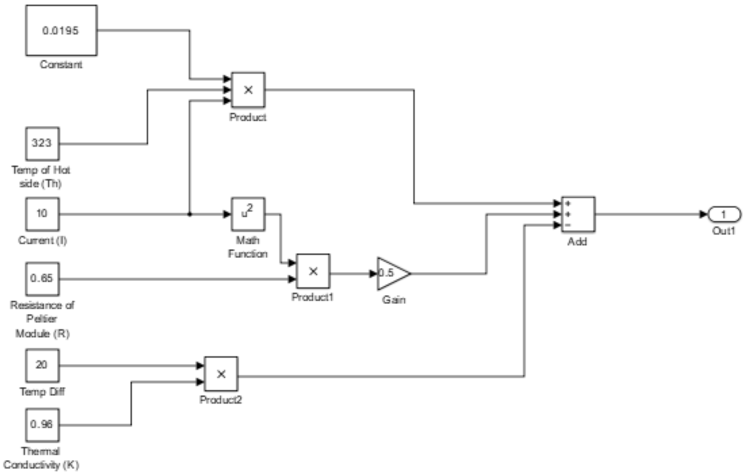

Figure 4. The MATLAB Simulink model of Peltier module.

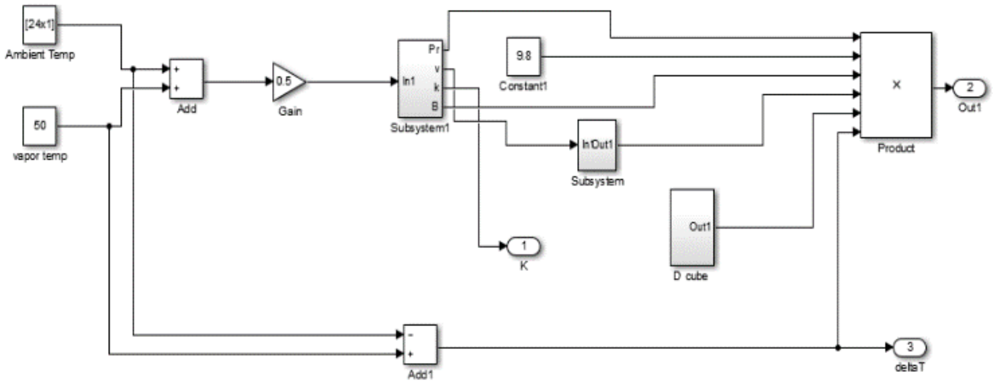

Figure 5. MATLAB Simulink model for Heat loss due to local ambient temperature.

IV. Results and Discussion

The simulation developed in MATLAB Simulink is receiving input electrical energy. The Peltier module creates temperature difference when electrical energy is applied. One junction of Peltier module becomes hot and the other side becomes cold.

In figure 6, Heat loss due to local ambient temperature from evaporated vapors is plotted for one day (27 May). The ambient temperature of Peshawar is selected as local ambient temperature. As in figure 3, local temperature of Peshawar is plotted for one day. As from 1 AM till sunrise the temperature decreases, the temperature difference between hot vapors and ambient temperature increases and due to which heat loss increases. From sunrise till 4 PM the ambient temperature increases, temperature difference between hot vapors and ambient decreases and therefore heat loss decreases. After sunset the ambient temperature decreases, temperature difference increases and convective heat loss from hot vapors to ambient increases.

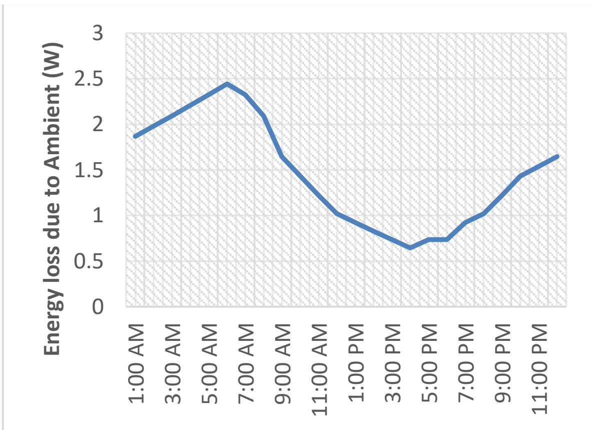

Figure 6. Simulation result of energy loss due to local ambient temperature

In figure 7, the COP of Peltier module is plotted for one day. As the ambient temperature increases, the COP of module increases. There are two reasons for increase in COP. The first reason is that as the ambient temperature increases, the heat loss due to ambient decreases and hence the COP of module increases. The second reason is that as the ambient temperature increases, the temperature of water also increases. As a result less heat is required to raise the temperature of water so the efficiency of Peltier module increases

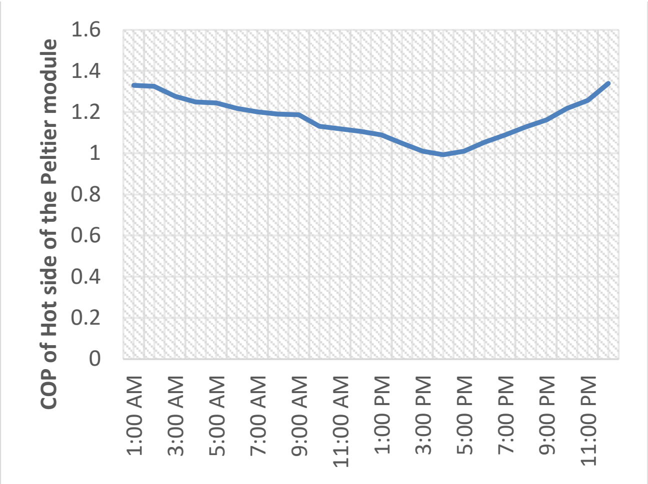

Figure 7. Co-efficient of Performance of Peltier module taking into account the ambient conditions.

In figure 8, COP of Peltier module is simulated for monthly average ambient temperature. It is found that as the average monthly temperature increases, the heat loss from the evaporator decrease and hence the COP of Peltier module is increased.

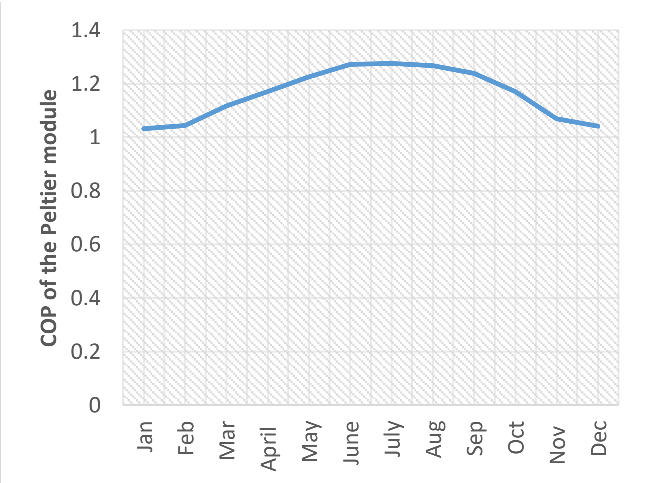

Figure 8. COP of Peltier module for monthly Average ambient temperature

Conflict of Interest

The author has no conflict of interest.

Conclusion

Based on the above results the following conclusions are made.

1) Ambient also play an important role in evaporation. Some heat from chamber where water evaporates, is loss due to temperature difference between local ambient temperature and hot vapors. Heat loss is maximum when temperature difference is maximum and heat loss is minimum when temperature difference is minimum. At 6 AM the heat loss has a maximum value of 2.4 watt and at 4 PM heat loss has minimum value of 0.6 watt.
2) The daily COP of Peltier module is a function of temperature difference between vapors temperature and ambient temperature. As the ambient temperature increases the COP of Peltier module increases and vice versa. In figure 7, the relative percentage difference between maximum and minimum COP is 20%.
3) The relative percentage difference between maximum and minimum COP for year (Figure 8) is 22 %. Which is reasonable that seasonal ambient conditions affects the efficiency of Peltier based evaporation

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How to cite this article:

Imtiaz Ahmad "Effect of Local Seasonal Temperature Variation on Energy Efficiency of Water Evaporation using Peltier Module", International Journal of Engineering Works, Vol. 8, Issue 07, PP. 180-184, July 2021, https://doi.org/10.34259/ijew.21.807180184.