A Review on Increasing the Efficiency of Parabolic Trough Type Solar Collector

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Abstract- *The global demand for energy is growing day by day due to this the conventional energy sources like coal, petroleum, natural gas etc are depleting, so the renewable energy will be in huge demand in future. One of the most commonly used sources of renewable energy is the solar energy. The methods of harnessing the full potential of the solar energy are still being discovered. One of the methods of harnessing solar energy is through parabolic trough solar collector. The parabolic trough solar collector is one of the types of concentrating solar power technologies. This paper presents an overview of the methods discovered by the experiments performed by the researchers including by experimenting with different heat transfer fluids, using the mixture of ethylene glycol and water, using glass envelope on the absorber tubes, optimizing thermal stresses by using finite element methods and also by introducing the eccentric tube receiver and some methods like concept of mirror surface cleaning, contamination, using vortex generator concept for passive cleaning for increasing the efficiency of parabolic trough solar collector.*

Keywords- Parabolic trough solar collector, Concentrating solar power, Heat transfer fluid, Renewable energy

I. INTRODUCTION

As the demand for energy is increasing day by day the conventional energy sources have began to deplete. The demand for energy is increasing due to the increasing population in the world and certainly after few years the conventional energy sources will be vanished from the earth. So the usage of renewable energy sources should be more so that the energy will be conserved [1, 2]. The total energy provided by renewable energy sources is 19.1% of total energy consumption daily [12]. One of the renewable energy sources which can contribute to the future energy demand is the solar energy. Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to the earth through space in form of energy called photons [6]. Only 30% of solar energy reaches the earth every 20 minutes, the sun produces enough power to the earth to fulfill the needs of the earth for an entire year. Sunlight provides by far the largest of all carbon-neutral energy sources. The total energy that strikes the earth from sunlight in one hour is 4.3×10^{20} J which is more than all the energy consumed on the planet in a year that is equal to 4.1×10^{20} J [8].The sun is of spherical shape having a diameter of 1.39×10^{9} m. The solar energy strikes our planet in 8 minutes and 20 seconds after leaving the sun which is 1.5×10^{11} m away. The sun has effective blackbody temperature of 5762k. The temperature in the central region is maximum around 8×10^{6} k to 40×10^{6} k. The sun's total energy output is 3.8×10^{20} MW which is equal to $63MW/m^2$ of the sun's surface. Only a tiny fraction of 1.7×10^{14} KW of total radiation emitted is intercepted by the earth [13]. Solar energy is permanent non-polluting and low running cost source of energy [1]. There are many other ways of utilizing the solar energy, one of the methods are concentrating solar power technology. The concentrating solar power technologies are used instead of flat plate collectors because it has more efficiency and concentrate the incident radiation on a suitable absorber or receiver [1]. The difference between the concentrating solar power technologies and other methods is that they first concentrates sun's energy on devices like troughs and then concentrated heat energy is transferred through a heat transfer medium to heating area [4]. The idea of using solar energy collectors to harness the sun's energy is recorded from prehistoric times. When the Greek Scientist Archimedes discovered a method to burn the Roman's fleet. He continuously set the attacking Roman fleet to five times of concave metallic mirrors in the form of hundred polished shields, and this is how solar collectors were discovered [13]. Parabolic trough solar collector is an element which concentrates the solar energy incident over a large surface to a smaller area [8]. It is a line concentrating element consisting of aperture diameter, rim angle, absorber size and focal length. It is generally used to focus the sunlight on the absorber tube which can be of mild steel or copper coated with a heat resistant black paint [8].Parabolic trough collector is a prominent and promising way to generate electricity with operating temperature up to 400◦C [12]. According to a study carried out by Pitz-Paal in 2007 found that the standard solar trough have efficiency of 54.2%, half of the energy that can be captured was lost due to the system deficiencies [8]. According to S & L 2003, the solar field efficiency is dependent on incident angle effects, solar field availability, collector tracking error and twist, the

geometric accuracy of mirrors to focus sunlight on the receiver, mirror reflectivity, cleanliness of the mirrors, shadowing of the receivers, transmittance of receiver glass envelope, absorption of solar energy by receiver, end losses and row to row shadowing [8]. The time required to erect the parabolic trough solar collector module is only sixty minutes [10]. The solar heating systems are widely known throughout the world for hot water supply and total solar hot water heating capacity based on solar thermal collector was estimated around 373GW at the end of 2013 and expanded up to 406GW at the end of 2014 [12].

II. METHODS FOR INCREASING THE EFFICIENCY OF PARABOLIC COLLECTOR

An experiment was carried out by Tadahmuh Ahmed Yassen et al. in 2009 on solar collectors on two different days during summer and winter at the roof of mechanical engineering department in Tikrit University and the readings were taken during 8AM to 4PM. They tried to increase the efficiency of solar collector by increasing the mass flow rate of water. Increasing the mass flow rate will decrease the absorber tube temperature and so the heat losses will decrease and the heat removal factor is improved. But it was observed that the efficiency improved only till the mass flow rate was 40kg/h after that there was no significant change in the efficiency. It was found that the thermal efficiency of the collector was more in winter as compared to summer by 2 to 5 percent. But the useful energy gained in summer was more compared to that of winter [1].

Husain- Al –Madani et al. carried out an experiment on a solar water heater in Bahrain consisting of an evacuated cylindrical glass tube. After testing the prototypes the temperature difference was found to be 27.8◦C and the maximum efficiency was 41.8% [2].

An experimental and numerical study of parabolic solar dish collector water heater with glass mirror was carried out by J. Parthipan et al. and B. Naglingeswara Raju et al. they demonstrated that the parabolic dish collector water heater is a good alternative for flat plate water heaters and the receiver is covered with glass cover, the system performance gets improved. It was seen that the efficiency was improved up to 4.19% with flow rate of 0.0075kg/s when receiver covered with glass. It was also found that with flow rate of 0.0075 kg/s with glass cover on the receiver the heat losses decreased up to 43%. And decrease of 18% in receiver temperature [3].

Mr. Aglawe et al, Mr. SS Giri et al, Ms. SR Jumade et al carried a simulation study on the thermal stresses induced in solar collector, they found that when the temperature of body increases or decrease then the expansion or contraction takes place and no stresses are produced in the body, but when the body is subjected to deformation then thermal stresses are produced in the body and corresponding strain induced is called thermal strain. Finite element methods are used for calculating the thermal stresses in different parts of solar collector. They calculated that the maximum shear stress should be 2.15×10^{7} Pa, directional deformation should be up to 3.6×10^{-6} m and maximum principal elastic strain should be up to 1.94×10^{-4} m for increasing the efficiency of parabolic trough solar collector [4].

Yong Shuai et al, Fu Qiang Wang et al, Xin-Lin Xia et al and He- Ping Tan et al introduced an eccentric tube receiver for increasing the efficiency of the solar collector. It was found after experiment that the thermal stresses were reduced up to 46.6 %. But the thermal stress reduction occurred only when the oriented angle was between 90◦ and 180◦ [5].

An experiment was carried out by J. Ramesh et al, J. Kanna Kumar et al, and Dr. EV Subbareddy et al on performance evaluation and comparison of the glass cover tubes of copper pipes in terms of efficiency. They found that at high temperature of 103◦C and high thermal efficiency at 98% due to high solar intensity, the solar collector gained heat more effectively whereas at 60◦C temperature on a sunny day the efficiency was found to be 63%. The highest heat gain was found to be 1500 W on a sunny day and lowest of 450 W on a rainy day. The solar intensity was approximately constant and varied depending upon rainy day or sunny day [6].

M.A.I.M Safian et al developed a modified design of parabolic trough solar collector with the tempered glass cover added to the trough to trap the solar radiation reflected from the surface to reduce heat losses. After that they carried out an experiment on two heat transfer fluids namely water and engine oil SAE 20 W50. It was found that the efficiency of the system with water as heat transfer fluid was more than the engine oil SAE 20 W50 for low temperature thermal recovery application [7].

Stacy L Figueredo et al presented many methods to increase the efficiency of parabolic trough solar collector by studying the monolithic molded trough design, evaluating the efficiency of mirror film surface and film abrasion effects, effects of contamination on reflector surface efficiency and design of vortex generator as a passive cleaning concept. This research was beneficial in increasing every percent of efficiency of the solar collector and overall efficiency was increased to some extent. It can also be used for other areas of energy research [8].

Eltahir Ahmed Mohamed et al experimented on concentrating collector on the roof of Mechanical Engineering Department of Nyala University at latitude of 12.1◦N, longitude 24.9◦E and elevation of 67m and configuration of collector was N-S orientation. The efficiency of collector was found to be 37%. But they found that after using glass envelope around the absorbing tube and using stainless steel pipes instead of galvanized pipes improved the efficiency of collector by 5% [9].

Singh H et al and Mishra RS et al performed an experiment on parabolic trough concentrating collector using ethylene glycol based mixture. They experimented with two different volume flow rates at 100L/h and 160L/h. They found that the thermal efficiency of collector for volume flow rate of 160L/h was more than that of the 100L/h at the middle of the day. But the overall efficiency for 100L/h with ethylene glycol mixture and distilled water was more compare to 160L/h. It was also found that with increase in solar intensity, the instantaneous efficiency and thermal efficiency was decreased [12].

III. DISCUSSION

The overall outcomes of the researchers have positive results on performing the experiments on the parabolic trough solar collector and the methods suggested improving the efficiency of the collectors. The recommendations given by the researchers can definitely increase the efficiency of the parabolic trough solar collector and will motivate people to use renewable energy sources.

After going through various experiments, it is found that efficiency of parabolic trough solar collector can be increased by increasing the mass flow rate of the water as heat transfer fluid but only up to 40kg/h, because after that the efficiency will start decreasing. By placing the glass cover on the absorber area the thermal stresses are being trapped and efficiency of collector is improved. Water gave more efficiency as heat transfer fluid as compared to engine oil. The mixture of ethylene glycol and water had more overall efficiency for low volume flow rate. Various methods like cleaning of mirror surface, contamination and using vortex generator as passive cleaning concept were also useful in increasing the efficiency of parabolic trough type solar collector.

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