Parabolic Trough Solar Concentrator

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Abstract:

Solar Energy is a renewable source of energy and available in abundance. Its uses do not contribute to emission of any greenhouse gases and other pollutants in the environment. Taking advantage of this, the potential for a solar-thermal system for hot water generation has been studied in this paper. This research was concerned with an experimental study of parabolic trough collector designed and manufactured to concentrate the solar energy. A parabolic trough solar collector(PTSC or PTC) uses GI sheet in the shape of a parabolic cylinder to reflect and concentrate radiations coming from the sun towards an absorber tube located exactly at the focus line of the parabolic cylinder. The receiver absorbs these incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the absorber tube. The designing and fabrication of parabolic trough solar water heater for water heating was executed, the procedure employed includes design, construction and testing stages. The model which is made up of reflector surface, reflector support, absorber pipe and a stand with manual tracking arrangement was fabricated using locally sourced material for rural applications point of view.

Key Word:Solar energy, Parabolic solar trough concentrator, efficiency, concentrator design analysis.

Introduction:

The problem of climate change caused by pollution of air, water and soil is increasing day by day. This is caused mainly due to continuous exploitation of fossil fuels resources. It is therefore essential to find a solution which allows production of CO2-free energy to meet our daily and industrial needs. The solar energy which is a renewable energy can be one such solution. It is free, reliable, domestic, and non-polluting source of energy, and can perfectly help to solve this problem. If calculated, the average solar energy reaching the earth in the tropical zone is about 1 kwh/m2 and total radiation over a day is at best about 7 kwh/m2 according to some information sources. Thus increased utilization of solar energy in our country which receives solar energy in abundance, would result in all around benefits, both in terms of cleaner environment as well as monetary gain.[1].The process of concentrating solar energy includes concentration of lenses or reflective mirrors in such a way that the sunrays falling over its surface are converged onto a target of a smaller size located at the focal plane of this surface.

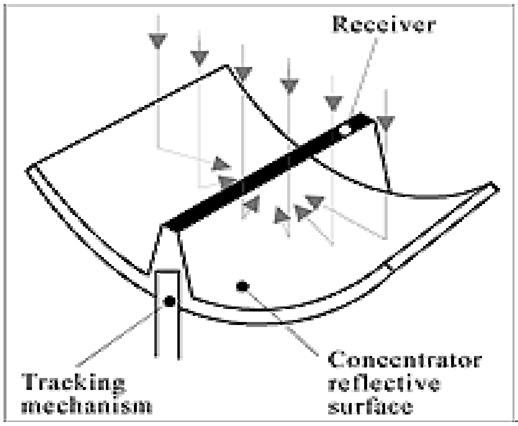
Generally, there are two main methods used to perform the concentration of solar energy.

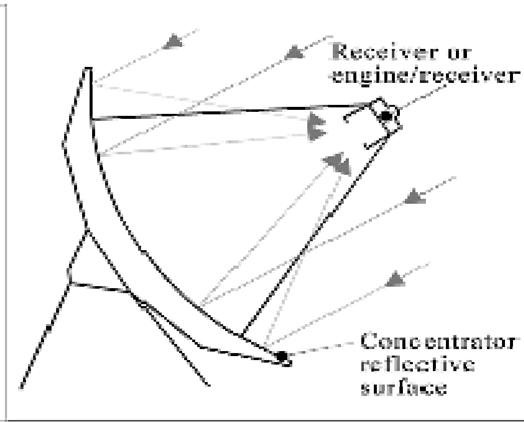
- Line-focusing systems: linear concentration.

 Point-focusing systems: concentration point[2]

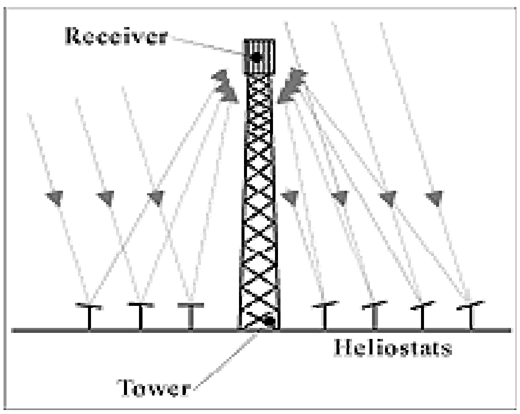
Types of solar concentrators:

- Parabolic trough system
- Parabolic dish
- Power tower





1.1Crossection of parabolic trough [3] 1.2 Crossection of parabolic dish [3].



1.3 Power tower system [3].

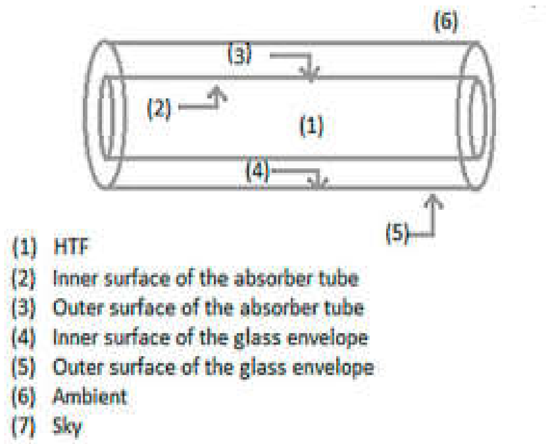
The extraction of this energy would be more advantageous in solar plants used for heating purpose by concentrating the sunlight.To achieve this, a model of parabolic solar trough collector considering new ideas was built using mineral oil nanofluid as working fluid with different types of receiver tubes. As a result of this, a significant increase of approx.11% wasachieved on the efficiency of the designed model.[4] Another method to improve the efficiency was attempted by using moltensalt as working fluid medium in the model of trough collector.[5]

A parabolic solar trough concentrator consists of a linear parabolic reflector which concentrates light onto a receiver placed along the focal line. It also consists of a receiver tube positioned at the middle of the parabolic mirror and filled with a working fluid. The reflector follows the sun during the daylight hours by tracking along a single axis. The working fluid present in the tube is heated to approx. 150–350 °C (300–660 °F) as it flows through the tube which is further used as heating medium for power generation.

The simple construction and good performance has made PTCs, the most efficient future solar technology for indirect steam generation in solar thermal plant. Compared to other available types, PTCs are the most installed in the worldas they can deliver temperature with good efficiency.In this experimental study the design and fabrication of parabolic trough solar water heater for water heating is observed and studied. The procedure employed includes the design, construction and testing stages. The equipment required such as the reflector surface, reflector support, absorber pipe and a stand are fabricated using locally sourced materials.

Physical model of absorber tube:

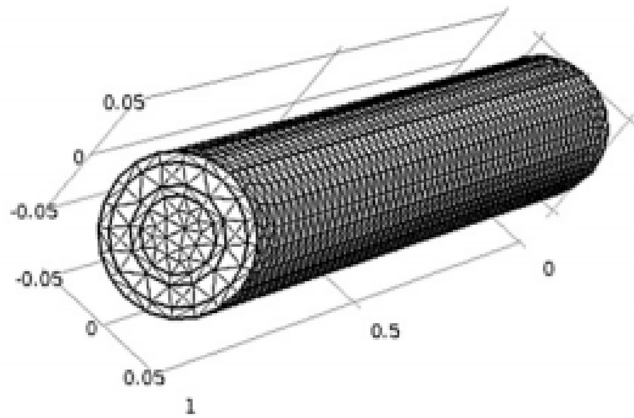
Currently, the improving of the performances of the PTCs has obtained huge attention, and thus many optical and Thermal studies have been realized.PTCs use heat transfer fluid (HTF) that flow inside the absorber tube that is covered.Performance of PTC totally counts on the absorber tube through which the working fluid flows and on which allthe solar energy is concentrated. The model is based on three-dimensional heat transfer through the receiver as shown in fig 2.1 [6]



2.1 Physical model parabolic collector [6]

PTC Geometry and the generated grids of absorber tube:

The data used in the present modelling is shown in Table 1. Once the absorber tube has been modeled, the model is then exported for meshing, which is a process where the model is divided into a finite number of smaller elements. The mesh size in this analysis is kept at normal (Fig. 2.2). [6]

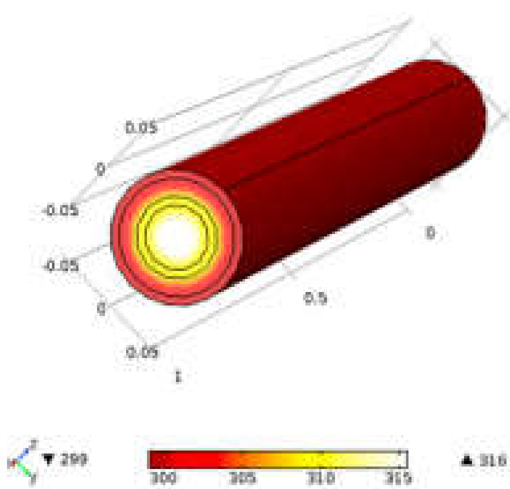


2.2 PTC Geometry and The generated grids [6]

Table 2.1 Model dimensions of absorber tube. [6]

Model dimensions	Value(m)
Length of collector	1
Outer diameter of absorber tube	0.030
nner diameter of absorber tube	0.0275
Outer diameter of glass cover	0.0575
Inner diameter of glass cover	0.050

Using COMSOL software, the temperature distribution of the receiver tube is carried out under unsteady state study. The temperature distribution is determined using water as heat transfer fluid. The three-dimensional temperature distribution of the receiver tube is shown in Fig. 3. The heat flux of the glass cover outer surface wall is 1000W/m2. The heat transfer occurs from the wall surface of the glass cover to the fluid. [6]



2.3 Temperature distribution of receiver tube [6]

The concentrated solar radiation is absorbed by the selective coating and converted to heat. The heat is then conducted to the inner surface, and subsequently, transferred via HTF through convection. Moreover, a part of heat is lost because of radiation in the annular gap. [7]

Design parameter of parabolic though collector:

The design parameter of a parabolic trough collector can be classified as geometric and functional. The geometric parameters of a PTC are its aperture width and length, rim angle, focal length, diameter of the receiver diameter of the glass envelope and the concentration ratio.The functional parameters of a PTC are optical efficiency, instantaneous and all dayThermal efficiency and receiver thermal losses. These parameters are largelyinfluenced by the absorptive of the absorber.[8]

Design analysis of PTC:

After conducting more research on solar energy and solar collection, the decision was made to attempt to build a parabolic trough solar concentrator. In a parabola all of the incoming rays from a light source (in this case the sun) are reflected back to the focal point of the parabola. If the said parabola is extended along an axis (becoming a trough) the solar rays are concentrated along a line through the focal point of the trough. The focal point of a parabola is located at 1/4a, if the equation of the parabola is y = ax2.[8]

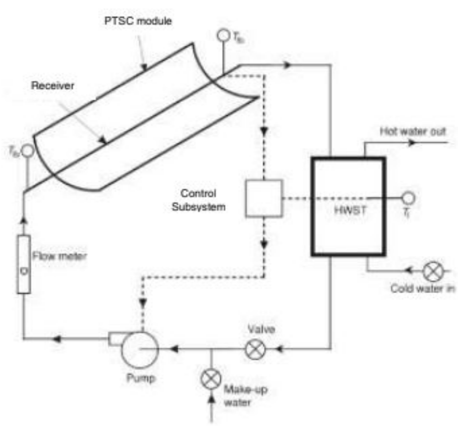


Fig 2.4 Simplified diagram of PTSC[9]

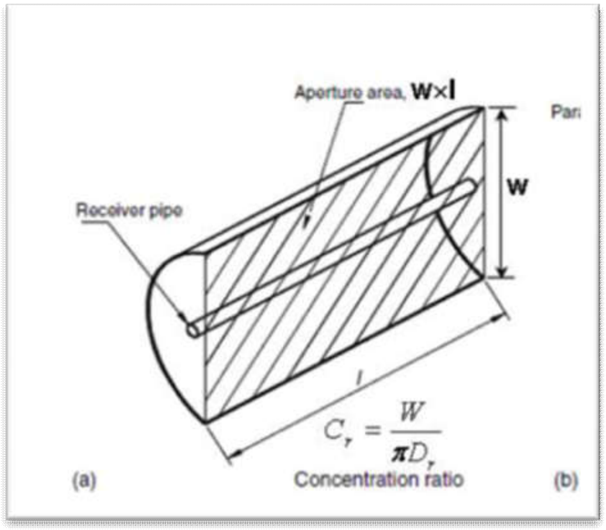
Geometry of Parabolic Trough Solar concentrator:

It consists of:

(I)A parabolic reflector of about 1-6 m aperture width

(ii)An absorber (receiver) tube made of steel or copper with diameter 1.5-5 cm and coated with selective coating

(iii)A concentric tubular glass cover surrounding receiver with a gap of about 1- 2 cm which is evacuated



3.1 Cross sectional view of PTSC

Performance enhancement techniques:

As one improves the performance of PTSC systems one ensures reduced system cost, improved overall system efficiency and subsequently improved system reliability. Because of these benefits, many researchers have considered a number of heat transfer enhancement techniques to improve the thermal performance of PTSCs. The performance of a PTSC can be enhanced by either changing its optical design or HCE properties, including augmentation techniques. In recent years, thermal enhancement in the HCE properties has been widely considered by many researchers rather than the optical design. In this section, all the efforts found in literature, including both the optical and the thermal improvements are presented.[10]

Efficiency:

The instantaneous efficiency of a PTC can be calculated from an energy balance on the receiver tube. It is defined as the rate at which useful energy is delivered to the working fluid per unit aperture area divided by the beam solar flux (at the collector aperture plane).According to the simulation results, the instantaneous efficiency is calculated as follows [6]

$$\eta = \frac{Q_u}{A_m I} = \frac{C_p m \left(t_{\text{out}} - t_{\text{in}}\right)}{A_m I},$$

Where,

ηopt is the optical efficiency of collector

Am is the opening area of parabolic mirror, m2

I is solar radiation intensity, (W/m^2)

Qu is the available energy of working fluid in the heating metal tube, (W)
qu is the surface heat flux of receiver, W/m2$D2$ is the external diameter of receiver tube, (mm)
L is the length of vacuum tube, m; $t$in is the temperature of fluid inlet, (∘ C)
$t$out is the average temperature of fluid outlet,(∘ C)
m is the mass flow of fluid,(kg/s).
Cp is specific heat (J/(kg·K)).
Also according to the simulated heat flux, the optical efficiency is calculated as follows. [6]

$$\eta_{\text{opt}} = \frac{q_u \pi D_2 L}{I A_m}.$$

Experimentsusing compound parabolic collector for direct steam generation have resulted a maximum thermal efficiencyof 35% and natural circulation heat pipe system with a thermal
efficiency up to 38.5%.[12]

Material:

Concentrator costs contribute to amajor portion of the total costing quoted for a solar thermal system. The heliostats or the glass mirrors used are estimated to account for about 40%-50% of the total cost of the power plant. One of the most promising solution to these heavy costs is the use of advanced optical materials in stretched-membrane designs. It can be noted that stretched membrane designs can reduce the initial costs by one-third or more, thus affordable for all. [13]
For this members of the solar manufacturing industry have proposed new goals, including mirrors that maintain high specular reflectance for extended lifetimes under outdoor service conditions with minimal costing to concentrator manufacturers. To increase the reflectance of the PTC surface and achieve maximum concentration at the focal line, various coatings of different materials are applied such as: [13]

- Protective Top Coats
- Directly Deposited Reflector Material
- Silvered Teflon TM Reflector Material
- Polymer Multilayer Reflector Material
- All Polymeric Reflector Material

Application:

- Hospitals
- Military areas

- Food preparation
- We know that natural gas (NG) has now become the largest single fuel in the global mix which can help the transition to a sustainable and clean energy scenario.NG is transported through several states by a tentacular infrastructure till distribution nodes. At this level, the NG predistribution treatments are conducted in the so-called pressure reduction station (PRS) and these include gas metering, filtering, preheating and pressure reduction. The gas preheating is essential to avoid the formation of methane hydrates that could result in pipe corrosion or component damage. For this purpose, the preheatingtemperature ranges between 55 C and 85 C depending on the system characteristics, NG composition and pressure drop.[15]

- Power plant:TSE1 is the first solar thermal power plant operating in Southeast Asia.The TSE1 plant is the first commercial power station with DSG in parabolic troughs.

➢ In this plant process includes pre-heating, evaporating and superheating water directly in the collector absorbers is called direct steam generation (DSG).

➢ This power plant outcomes are The turbine of TSE1 operates at 330 °C, but solar field operation at higher temperatures up to 550 °C has been demonstrated [17]

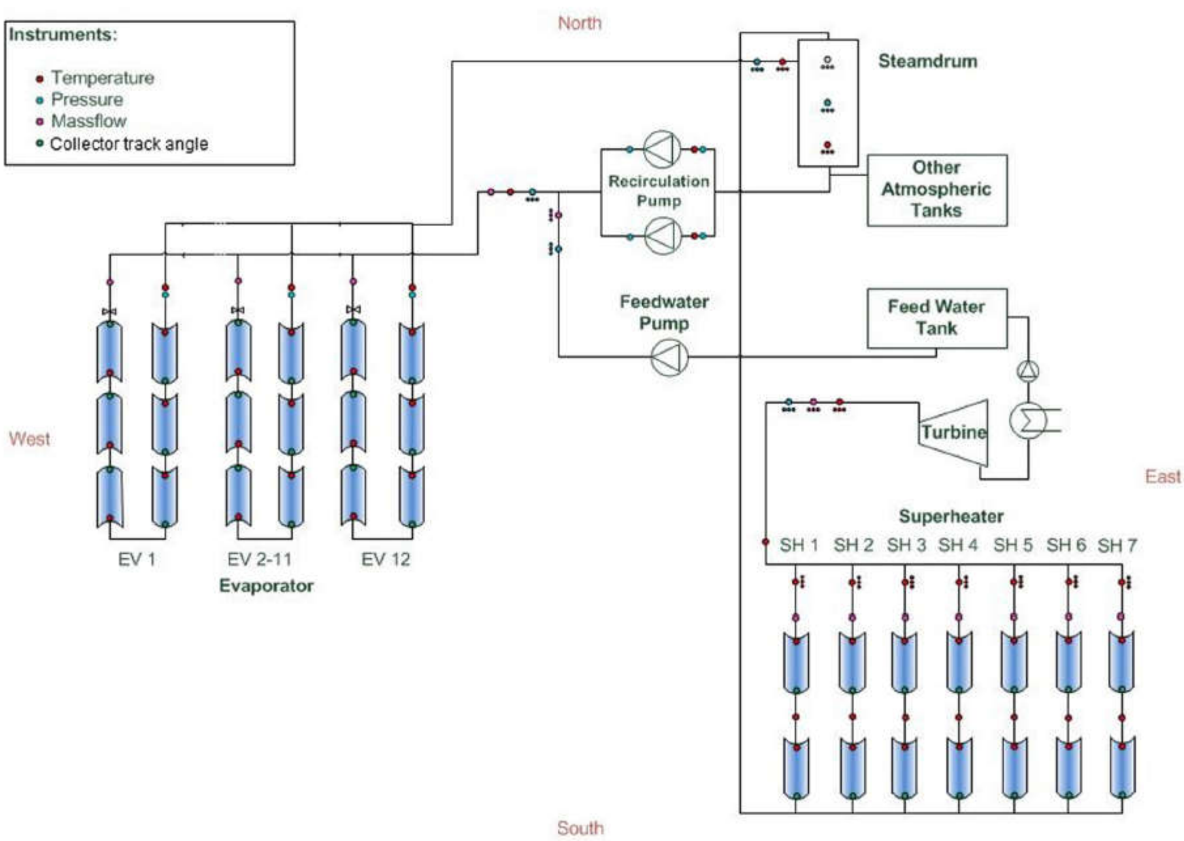


Fig.4.1Schematic P&ID of TSE1 with selected sensors. [17]

Conclusion:

This work presents a reproducible parabolic trough solar water heater as a suitable renewable technology for solar water heating, along with modern optical concentrating technologies as important parameter to provide energy in bulk amount in the form of heat.The main advantage of these PTCs is that they generate good efficiency using natural source of energy without any harm to the environment. They can be used to generate saturated steam which can be further used for running various applications on industrial level, thus reducing load on fossil fuels. Thefabrication and design of these PTCs using locallyavailable materials makes low temperature troughs a better solar thermal device for the rural and remote area.This paper might significantly help increase the knowledge and awareness on implementation of parabolic solar concentrators on small scale level.

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