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ANALYSIS THE EFFICIENCY OF SOLAR WATER DESALINATION SYSTEM: AN EXPERIMENTAL STUDY

Atif Saeed[1], Mukarram Hussain Shah[2],ShayanShahid[3]

[1,2,3]Department of Mechatronics Engineering, SZABIST, Karachi, Pakistan

Email: [1]m.atif@szabist.edu.pk, [2]mukkaramshah1@gmail.com, [3]shayan.shahid1@nixorcollege.edu.pk

Corresponding Author: Atif Saeed

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Abstract

Concentrated Solar Power can be the solution of today. Solar power being available in plenty can be harnessed using many of the concentrated solar power technologies. Climate changes are observed throughout the world and according to research reports, fresh water resources are drying up at a very high rate. In order to tackle the need of fresh water, Concentrated Solar desalination is prosed. Parabolic trough collector technology is to be employed with simple distillation phenomenon. Construction, calculations, implementation and results would be discussed in this report.

Keywords: Desalination, Solar Energy Harvesting, Efficient system, Mechanical Experimentation.

I. Introduction

The meteoric increase in the number of industries, vehicles and general standard of living has caused immense use and sometimes overuse of fresh water which is already very scarce in supply. These reserves of fresh water are fast depleting in result of our uncapped and unsupervised use. The fresh water needs of the country need to be fulfilled in order to maintain a healthy and feasible environment across the population. There is great scope in producing fresh water from solar desalination plants. Typically the combustion of fossil fuels lead to energy being produced which through a series of interconnected processes and stages converts water into fresh water. Energy is so very vital for any process to take place, as the desalination plat requires a lot of energy to do a tedious task of producing fresh water, the use of it needs to be carefully monitored and every option studied carefully to select the best

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possible answer to the energy conundrum .Energy can be divided broadly into two major classes [I–IV]

I. Renewable Energy
II. Non Renewable Energy

Renewable Energy

Renewable energy is the name given to the class of energy that is self-sufficient or unlimited in terms of the quantity. They are naturally occurring phenomena's and we have no control over their renewal. The biggest contributing factors to the selection of renewable energy as a source of energy is the fact that it provides us with absolutely clean energy with almost zero degree of pollutants introduced into the environment. Some examples of renewable energy are listed below:

I. Wind Energy
II. Solar Energy
III. Geothermal Energy
IV. Marine Energy
V. Biofuel

Solar Energy in Pakistan

Solar energy is the most abundant energy in the world with its reach reaching almost all across the globe. It is of special importance in Pakistan as it is predominantly a dry country with sunshine available for most part of the day. Pakistan is already an energy scarce country so search for alternatives is a never ending campaign for the people at the helm of affairs. Solar energy can easily solve this problem if it can be used at a large enough scale. This, solar energy can be of special use when considering its application in the process of solar desalination to produce fresh water. A mean analysis shows that Pakistan receives about 5-7 kWh/m²/day but most of it is wasted or underused [V–VII].

Not long ago 16 independent organizations have shown a desire to create and operate solar PV power plants with approvals gained by one and other waiting in line for feasibility report. Other initiatives are also taken to provide a much larger application of solar energy in the country

I. The electrification of solar village with approximately 3000 homes in almost 50 districts of Tharparkar. Addition of another 50 villages is inderway in Sindh as well as a whopping 300 villages in Balochistan have gained approval for the conversion to solar energy use.
II. The conversion of gas/diesel tube wells into solar energy has also been underway to make sure that the power grid is not solely dependant on the conventional methods of energy. Feasiblity reports are also being developed to study the viablity of the project.

With plentiful supply of solar energy and with correct framework provided to tap into a very high rewarding energy source, its true potential can be achieved this will be a groundbreaking achievement for Pakistan.

Problem Statement

Water is by far the most essential nutrient required by the human body. Not only does it benefit us internally but is a utility for all external purposes as well. Its increasing consumption needs to be fully satisfied major because of health concerns. Under the country's current situation where water management is under severe stress due to its scarcity and pollution. Alternative methods need to be sort after for the development of the country.

Problem Solution

The process of removing salinity (salt) from seawater is not only an alternative but a very logical process of making use of the abundant seawater that Pakistan possesses. Water crisis is expected to get worse largely due to the impending adverse changes in climate globally due to pollution across the globe. Concentrated Solar Power (CSP) makes use of lenses and mirrors to focus the solar energy into a localized spot using special tracking system to track the correct orientation of the sun. The energy derived is reserved in the thermal collector which is largely fluid based.

II. Methodology

The main method by which all this process is done is using the parabolic trough collector that focuses the sun's heat radiation into miniaturized but high energy beams that is stored in the fluid based thermal collectors. The fluid layer in the receiver tube absorbs all the heat and transfers it to the salty water there already in the heat exchanger. This as a result boils the water and the steam generated from it will move towards the condenser. The condenser than converts the steam into water droplets which are distilled and very safe for drinking use. The presence of vacuum in both the heat exchanger and the condenser is very vital for efficient working of the system [VIII–X].

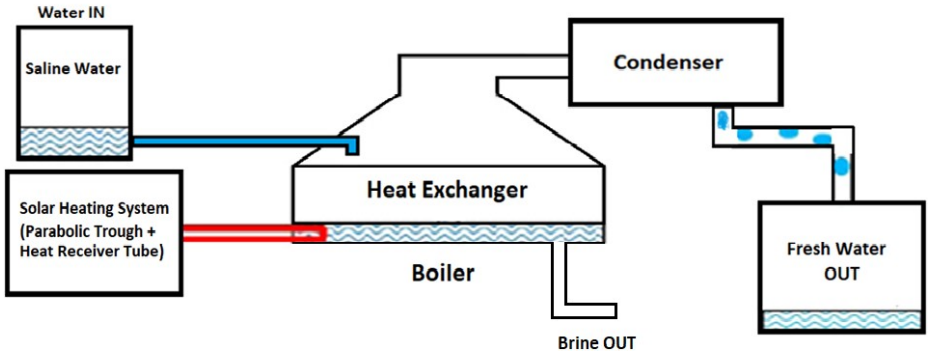

Fig 1. Schematic Diagram of Solar Concentrated Desalination Plant

Freshwater supply is a very vital component in the stability of a modern society. With the limitations associated with ground water and rainfall in Pakistan, other methods need to be sort after. Pakistan being a dry country with ample solar radiation with almost 300 sunny days out of 365 days which is a whopping 82 % to bolster can be utilized very effectively and efficiently to provide substitute resources for fresh water supply. Conventional processes of Reverse Osmosis (RO), Multi stage flash (MSF), Multi effect distillation (MED) and Electro-dialysis (ED) have gradually improved into processes with much broader scope and objectives. Solar desalination has yet not be marketed or commercialized in a way that it deserves in Pakistan but soon with the advent of newer and fresh products it will gain increased popularity according to its true potential. Concentrated Solar Power (CSP) is truly a game changer in a sense that not only does it provide us with our desired output which is freshwater but also the fact that it fulfills its objectives in such an effortless way by making use of the most abundant resource that is Sun's energy and directing it towards a concentrated goal using basic and elemental tools like lenses and mirrors [XI–XV].

If done properly the achievements of the project far outweigh whatever demerits or limitations of the project which is a huge bonus for a project which is in its prototype phase.

The solar collector trough mechanism has many benefits and applications for Pakistan's household and industrial use as it makes available for us the most important resource these days. In addition to this it can also be used in the following tasks:

I. Food industry for hot water production.
II. Dairy industry for hot water production, as hot water is used in dairy industry for cleaning purpose.
III. Leather industry (tanneries)
IV. Air-conditioning.

Construction of Parabolic Trough

In the first phase, the wooden mold was constructed. The mold length was 4*5 feet and the wood chosen for it was lasani wood. In the second phase angled iron standing support was constructed. The stand was given the truss structure look to give it further support to bear weight of the parabolic trough collector. The angle iron used is 1/8 in thick and the frame is approximately 3 feet above the base.

Fig 2. Gearing Mechanism

In the third phase we attached the reflecting surface on the parabolic trough, several thin reflective films were used but the results were not satisfying. We obtained a high reflection stainless steel sheet and tried it as our reflective film. Satisfactory reflection was obtained that enabled us to perform the tests.

Fig 3. Parabola with reflective sheet

Now the main work was to make the support to hold our receiver tube, we needed the moveable attachment of the receiver tube in order to find the exact focal line. So we attached the moveable plates on the side support of the parabola for the translational movement along z-axis.

Fig 4. Parabola with side support/final design

Construction of Evacuated Tube

The receiver tube is one of the most essential part of this project. We wanted the receiver tube to be cost effective because the tubes sold by the manufacturing companies are very expensive to be used for this purpose. Number of different experiments were carried out using different tube materials from metals to plastics in order to make a collector tube that is cost effective and efficient. After testing several tubes which took us more than 6 months, we started to get results from the tubes. Most of the tests were not satisfactory so every time we would have to start from the beginning in order to construct an evacuated tube. In the end, we decided to use a Copper tube enclosed in a glass tube which is the same design the manufacturing companies are using. The challenge was to construct the glass tube. A few important things were to be considered. The expansion of copper at high temperature can easily break the glass tube, therefore expansion bellows were made in order to compensate for the expansion of the copper tube. The lengthof the glass tube is 5 feet.

Fig 5. Receiver Tube

Construction of Heat Exchanger

The shell and tube heat exchanger was constructed for the heat transfer between the thermal fluid and saline water. Shell and tube are the most common type of heat exchanger in oil refineries and other large chemical processes, and is suitable for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids.We used one shell pass Heat Exchanger.

Fig 6. Heat exchnager front view

Fig 7. Heat exchnager side view

Solar Tracking System

To get the maximum energy from sun solar tracking was required to track the sun whole day.These devices change their orientation throughout the day to follow the sun's path to maximize energy capture. LDR array circuit was used with arduinonano as controller. The motor used in our project is the linear actuator attached with gear mechanism.

The tracking mechanism consists of a linear actuator, gear mechanism, motor driver, LDRs and arduinonano as Micro-controller.

The algorithm for solar tracking is very simple, if the ldr at east gets the more intensity compare to west it will give +12volts and the motor will rotate clockwise and vise versa.The block diagram of solar tracking is shown in figure.

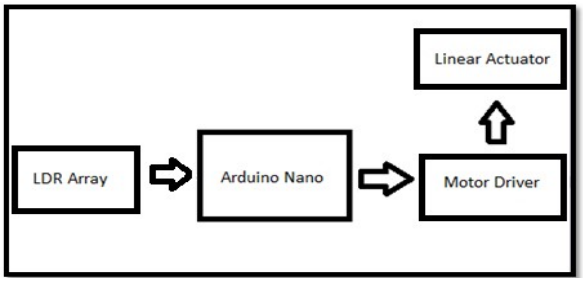

Fig 8. Block Diagram of solar tracker

III. Results and Discussions

Experiment # 1

The objective was to get the desired temperature out at the other end of evacuated tube. The results are should in Table 1.

Tube Used:

Evacuated Tube used for Solar Heaters.

Weather Condition:

Average temperature of 36 degrees.

Table- 1:Experiment 1 results

Time (minutes)	Temp (degrees)
0	32
5	43
10	57
15	68
20	92
25	107
30	130
35	158
40	172
45	180
50	188
55	193
60	196
65	200
70	198

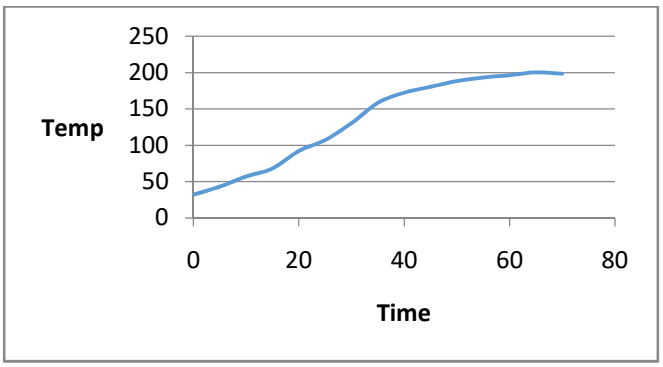

Fig 9. Temp Vs Time graph (Evacuated Tube used for Solar Heaters)

We were able to achieve around 200 degrees in an open loop system.

Discussion:

A very high temperature was achieved, the reason being, the use of very high efficiency evacuated tube that is used in solar heaters. The only reason of not using this tube for our project is the closure of the tube at one end which would not be fit for a closed loop system.

Fig 10. Experiment 1 (Evacuated Tube used for Solar Heaters)

Experiment # 2

The objective of this experiment was to get the desired temperature out at the other end of evacuated tube. The results are shown in Table 2.

Tube Used:

Stainless Steel (without insulation)

Weather Condition:

Average temperature was 36 degrees.

Table- 2:Experiment 2 results

Time (minutes)	Temp (Degrees)
0	33
5	38
10	45
20	57
30	62
40	68
50	71
60	73
70	75
80	74
90	73

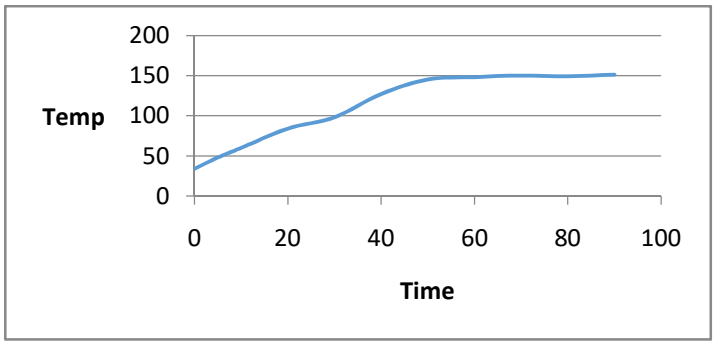

Fig 11. Temp Vs Time graph Stainless Steel (without insulation)

We were able to achieve 75 degrees having open loop system.

Discussion:

Thermal conductivity of Stainless steel is very low. High heat loss due to the absence of insulation, therefore, compared to the previous test, the efficiency of this tube is very low.

Fig 12. Experiment 2(Stainless Steel (without insulation))

Experiment # 3

The objective was to get the desired temperature out at the other end of evacuated tube. Results shown in Table 3.

Tube Used:

Stainless Steel (insulated).

Weather Condition:

Average Temperature was 35 degrees.

Table- 3:Experiment 3 results

Time (minutes)	Temp (Degrees)
0	34
5	48
10	60
20	84
30	98
40	127
50	145
60	148
70	150
80	149

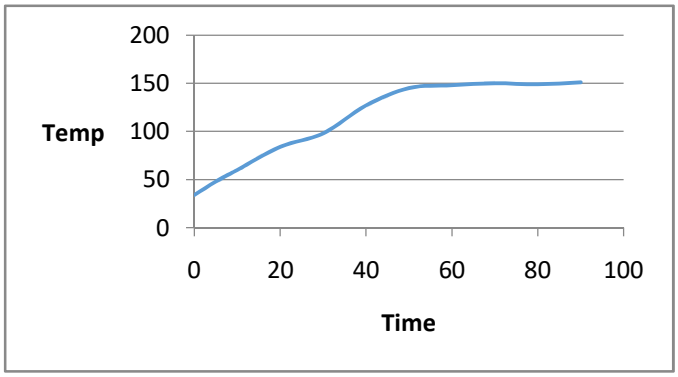

Fig 13. Temp Vs Time graph Stainless Steel (Insulated)

Obtained 150 degrees in open loop system.

Discussion:

A much better result was obatined using the stainless steel tube with good insualtion to minimize the heat loss. Stainless Steel tube was not further used because of its low thermal conductivity.

Fig 14. Experiment 3 (Stainless steel insulated tube)

Experiment # 4

The objective was to get the desired temperature out at the other end of evacuated tube.

Tube Used:

Copper tube inside the Acrylic Tube and a vacuum envelope between them.
Acrylic Tube**: Length** 5ft , 5mm thickness and 4 inch Diameter

Copper Tube **:** Length 5ft , 5mm thickness and 1.2 inch Diameter

Weather Condition:

Average Temperature 35 degrees.

Table- 4:Experiment 4 results

Time(minutes)	Temp (Degrees)
0	37
15	54
20	53
25	61
30	60
35	65
40	64
45	68
50	71
60	72

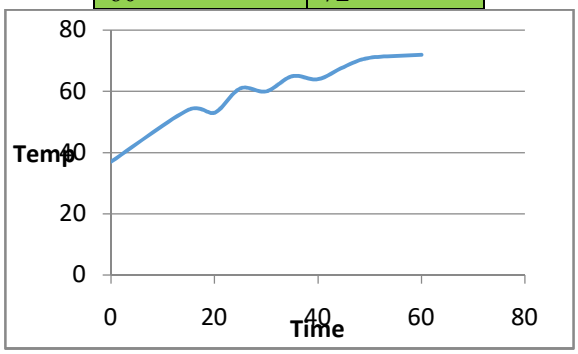

Fig 15. Temp VS Time graph (Acrylic Tube)

Discussion:

Acrylic tube with a vacuum envelope gave good experimental results in closed loop system. The acrylic tube having low melting point started deforming at the focal line therefore it had to be replaced by a glass tube.

Fig 16. Experiment 4 (Acrylic tube)

IV. Conclusion

The collector is made in a design, it can be easily disassembled and assembled, hence making it portable i.e. easy to transport and install. The algorithm used for sun tracking can be misleading since cloud covering and reflected light due to other atmospheric areas are ignored, therefore it may not track the sun precisely. The maintenance cost is low, that makes it economical, but due to the humid climatic conditions, structure is prone to rust and should be regularly inspected for rust.The system has negligible running cost and availability of cheap labor in Pakistan and simple design makes it implementable and doable with commercial viewpoint.

There are certain limitations associated with it as well, that is, it is limited to the clear sunny days only. Energy from the sun is an intermittent supply and converted energy cannot be stored, but has to be exchanged instantly. The Solar trough tilting angle is limited to a maximum of 120°. This research has single axis solar tracking mechanism, which needs regular monitoring. Periodic maintenance and monitoring is also required regularly since trough needs to be checked for dirt and deposition on the glass surface. It is non-polluting and environmental friendly technology which is a huge bonus since the conventional forms of energy are causing the greenhouse effect by depleting the ozone layer in the atmosphere.

The converted energy from the PTC can be used for several applications, such as:

I. Power generation
II. Water heating
III. Food industry for hot water production.
IV. Dairy industry for hot water production

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