Design and Optimized Control of Tracking Parabolic Trough Collector For Industrial Heating of Water in Islamabad, Pakistan

By

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Certificate

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I dedicate my effort to the builders of nation and my teachers.

Acknowledgment

First of all, I want to thank Allah Almighty, The Most Beneficent The Most Merciful Who made me able to complete this project. No words are sufficient to express my gratitude to my loving parents for their exemplary patience, understanding and co-operation during my Thesis.

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I hope that you will find this effort better than ever before.

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Abstract

The hot water and steam is used in various processes and production stages in different industries. Traditionally, they are generating steam and hot water from natural gas and furnace oil. But the country is already facing a huge shortage of natural gas and electric power. Meeting domestic requirements of gas and electricity is becoming difficult day by day, so it's the time to move on Renewable rather than relying on the conventional resources. The use of solar is one of the best options. Pakistan geographically lies on sun belt having maximum solar radiance and sun shine of almost 6 - 8 hours a day. The main theme of the project is designing, developing, testing and evaluation of single-axis solar tracking parabolic trough collector (PTC), which will act as a prototype for instructional and demonstrative purposes. A parabolic trough collector (PTC) having area of almost $4m^2$ and weight of 65kg was constructed. The proper dimension of the parabolic trough collector (PTC) was calculated using parabolic calculator and to verify the design its first constructed on AUTOCAD. The parabolic trough collector (PTC) was examined under different weather condition. COMSOL was used to simulate heat exchanger and the maximum temperature of 98˚C for the hot water was obtained The single axis tracking system was applied and results were compared with the fixed. The average efficiency of the tracking PTC was 50% more than the identical fixed collector. The cost analysis is also performed based on the actual value of usage of conventional resource, discussing the case of specific industry and the compensation which the parabolic trough collector has done by introducing as an integrated system. This system will be cost effective tracking system and significant for heating applications.

Keywords. Parabolic trough collector (PTC), parabolic calculator, AUTOCAD, Tracking, COMSOL

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List of Journal Paper

- Husnain Bhatti, Muhammad Bilal Khan, Waqar Ahmad, Shamir Ahmad, Irfan Niazi, "Design and analysis of single axis sun tracking parabolic trough collector for industrial water heating" Energy sources, Part A: Recovery , Utilization and Environmental Effects (Paper submitted)

  Attached at Annexure I

List of abbreviation

PTC .... Parabolic trough collector
EDB ....Energy Development Board
PCRET ....Pakistan Council of Renewable Energy technologies
LEC...Levelized electricity cost
CPC...Concentrated power collector
DNI ....Direct normal irradiation
LDR...Light dependent resistor
MMBTU..Million Metric British Thermal Units
1-D...One dimensional
3-D...Three dimension
°C...Degree centigrade
I°.. Parabola width
D°...Outer diameter of absorber pipe
π..Pi
ή...Efficiency
C_P...Specific heat
%...Percentage
C...concentration ratio
a...focus point

Chapter 1

INTRODUCTION

1.1Present scenario

Energy crisis in Pakistan is one of the serious challenges the country is facing today. Electricity, gas, water and fuel are necessary part of our daily life and its outage has badly influenced our economy and living. Increase in industrial activity and failure to provide enough energy from conventional resources has really harmed the country. Currently Pakistan is producing:

- 29.1% from hydropower.
- 5% from nuclear energy rest of the world is 16%
- 29.5% of electricity through gas while rest of the world is 19%
- 0.1% from coal while India and China using more than 40%from it.
- 36.3% from oil while rest of the world is only 7%.

Whereas Pakistan meets more than 80 percent of its oil demand through imports. Large amount is used to import oil for the production of electricity that's why the cost of electricity increased day by day due to the increase in the prices of oil[1]. The resources of fossil fuel which are available are being depleting so rapidly that they have reached their peak value and now being declining so may be available for the next 20 to 30 years. The resources of fossil fuel which are available are becoming so expensive and depleting.

1.2 Problem Facing

Traditionally, there are two energy sources of generating hot water in industry.

1. Heating using "Fire" through gas coal, and furnace oil etc.
2. Heating using "Electric Power".

The industry is spending huge amount for gas, oil and electricity. As the country is already facing shortage of gas and electric power, meeting the domestic requirements of gas and electricity is becoming difficult .It is an important question for industrial sector that how long more will they depend on conventional resources.

1.3 Industries affected

The hot water and steam is used in various processes and production stages in Pakistan. The major user of hot water and steam include:

- Textiles spinning and processing Industry
- Leather processing industry
- Food processing industry
- Sugar industry
- Chemical industry

So it's the right time to move on Renewable rather than relying on the conventional resources which are depleting rapidly. Development and promotion of new alternate and renewable sources of energy such as solar, wind and bio-energy etc are now getting sustained attention [2].

1.4 Why solar energy

Besides these two sources of heating, there is a third source of heating which is the "Solar". But unfortunately this source has not explored systematically in Pakistan. Most of Pakistan lies in sunny belt of the earth, with the sun shine of 6 – 8.5 hours daily having the greatest amount of radiant energy more than 90% of solar radiation is available all over the area within the boundaries except the cloudy days. The topographical picture of our country is given below.

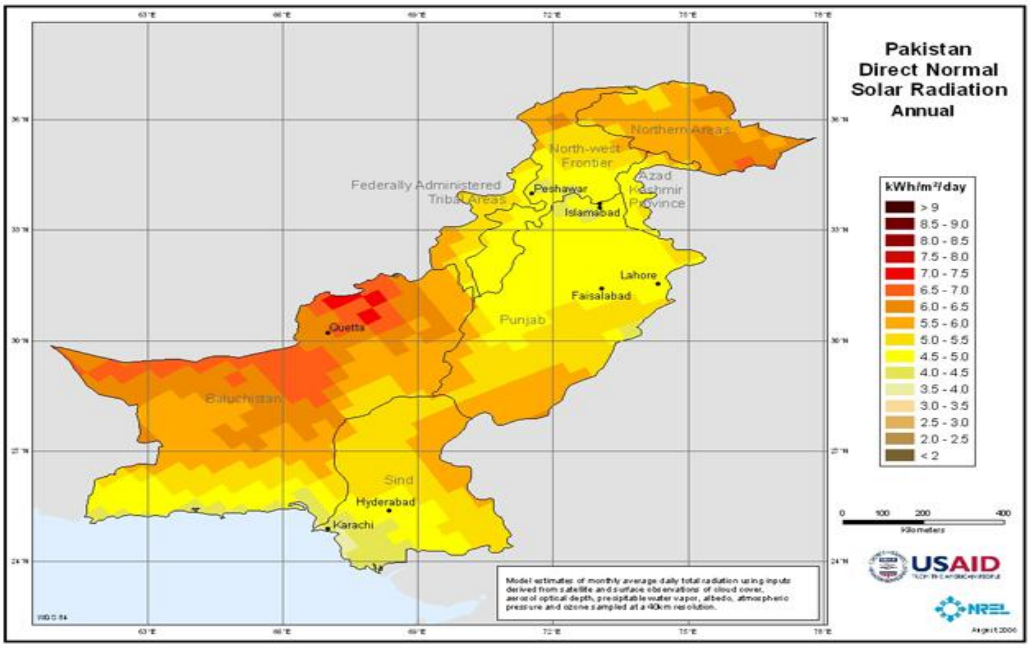

Fig. 1.1 Annual average daily solar radiation

Annual average daily solar radiation received throughout the country varies from 4.7 to 6.2 kWh/m^2 as shown in figure 1.1. The mean is somewhere at 5.45 kWh/m^2 [3]. The lower value at 4.7 kWh/m^2 is on higher side as compared with any European country who utilize solar radiation for their domestic & industrial use.

1.5 Scope

The project under description is not being initiated for the first time, all over the world, specifically in USA, Egypt and Australia there are large systems based on Sun-Tracked Solar Collectors. These solar collectors are used for:

- Thermal Heating
- Steam Generation
- Solar electric Power Generation
- Solar Furnaces for melting the metals
- Operating huge Air Conditioning Plants(100ton to 400 ton cooling capacity)
- Lithium Bromide Absorption Chiller

In Pakistan, there is a great potential to develop solar based systems both for domestic and industrial use. These systems may be developed using Solar Parabolic Troughs. Certainly, these systems will be more beneficial for our use as compared with the systems installed in western countries. Setting up of Pilot Projects in the public sector for Alternate renewable energy technologies of strategic importance e.g. wind, solar, waste to energy etc. in order to remove certain risk perceptions associated with such projects in Pakistan [4]. Different concentrating technologies have been developed or are currently under testing face for different applications in solar all over the world. The Parabolic Trough Solar Collectors system will certainly play important role to provide well-organized, cost-effective, environment friendly energy supply all around the world in next 5 -10 years [5].

1.6 Motivation

The government of Pakistan is also keen interested towards using Solar Energy. Energy Development Board (EDB) Ministry of Industry & Production, Ministry of Science and technology and Pakistan Council of Renewable Energy technologies (PCRET) have jointly initiated a project on "design development and installation of solar parabolic trough for hot water and steam for industrial process" [6].

The Proposed study will be really helpful for above mentioned project as prototype. The present system installed in industry are fixed, So by introducing tracked system we can maximize the efficiency and get best use of the solar energy.

1.7 Objective

The main objective of the project is:

- Design and develop a solar tracking system for water heating application.

- Observe the performance of the system by keeping it fixed and then advanced it to 1-D.
- Compare and analyze the different parameters like temperature, efficiency etc of both cases under the climatic condition of Islamabad.

1.8 Project Justifications

Development and Installation of Sun-Tracked Parabolic trough collector for heating water for industrial processes. The design and efficiency data will be used to set up an industry which will be producing the sun-tracked solar collectors to cater the needs of industries.

In fact gas and electricity are used for domestic and industrial use, the consumption of gas and electric power for generating the Hot Water and Steam for industrial use can also be met by using Sun-Tracked Solar Collectors. The water available to industries is found to be at tanks at ambient temperature. Average temperature range is 15^{o}C in winter to 40 ^{o}C in summer times. A big fire through gas or furnace oil or electric power is used to heat this water at ambient temperature. At least in the day times this consumption of gas, furnace oil or electric power may be minimized by introducing the Sun-Tracked Solar Collectors.

Normally, solar collectors are used to pre-heat water coming at ambient temperature and fed to the boilers. A 12 feet long parabolic trough type solar collectors is made which can raise the temperature of incoming water round 85 ^{o}C to 90 ^{o}C .If we are interesting in generating steam ,then heating more the water from outlet of parabolic trough collector at 85 ^{o}- 90 ^{o}C by using gas, furnace or electric energy can generate steam at 100 ^{o}C and requires a little gas, furnace oil or electric power. This combine system is known as Solar-Hybrid Steam Generator. It is notable that billing of Sun –Tracked Solar-hybrid steam generator becomes as low as 8% to 12 % of that the gas fire, furnace oil fired or electric power. In other words the consumption of gas, furnace oil or electricity becomes as low as 88% to 92% during the day light.

1.9 Social benefits and economical benefits

If the project is implemented practically in industries on large scale can lead to great social and economical benefits like:

- The solar based heating is generated free of cost (only one time investment is required to install these collectors).

- Gas and electric energy savings through solar based heating and/or steam generation would be a national contribution to overcome the demand of gas and electricity supplies for domestic and industrial use.
- The Sun -Tracked Solar collectors generate pollution free energy and help industries to share the national and world wide campaign on Clean Energy and Green Energy.
- A solution against the worst energy crisis, create the awareness in the people regarding solar energy and to motivate the people to move towards the alternate energy resources.

Summary

The prototype of parabolic trough collector is utilized which can act as demonstrable project for the industries of the Pakistan, that its really reliable and useful renewable gadget. The industry is spending huge amount for gas, furnace oil, electricity and how long more will they depend on conventional resources. So the Solar is the best option for Pakistan as most of it area lies in Sun Belt having annual average daily solar radiation between 4.7 kWh/m^2 to 6.2 kWh/m^2 and its free of cost (only one time investment which convert into profit after sometime).

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References

[1].Sahir, M.H. and A.H. Qureshi, Assessment of new and renewable energy resources potential and identification of barriers to their significant utilization in Pakistan. Renewable and Sustainable Energy Reviews, 2008. 12(1): p. 290-298.

[2].Bhutto, A.W., A.A. Bazmi, and G. Zahedi, Greener energy: issues and challenges for Pakistan—solar energy prospective. Renewable and Sustainable Energy Reviews, 2012. 16(5): p. 2762-2780.

[3].Sukhera, M. and M. Pasha, Solar radiation maps for Pakistan. Solar & wind technology, 1987. 4(2): p. 229-238.

[4].Farooqui, S.Z., Prospects of renewables penetration in the energy mix of Pakistan. Renewable and Sustainable Energy Reviews, 2014. 29: p. 693-700.

[5].Raja, N.K., et al., Design and Manufacturing of Parabolic Trough Solar Collector System for a Developing Country Pakistan. Journal of American Science, 2011.

[6].xperts-job-engineering-development-board-edb-pcret-job-two-senior- engineer, www.jobinpk.com.(06-12-2013).

Chapter 2

LITERATURE REVIEW

2.1 Solar collectors

Solar thermal collector uses the sunlight for heating purpose. The collector is used for converting energy from solar radiation into a functional and utilize form .The energy is transfer from the sun to earth in the form of electromagnetic radiation lies between infrared and ultraviolet region. the different factors like climate situation, location and direction of the surface effects the solar energy reaching to earth, but approximately its 1000 watts per square meter on a clear sunny.

2.1.1 Classification of solar collector

Solar collectors classified into two distinct categories:

a) Non-concentrating collectors
b) Concentrating collectors

a) Non-concentrating collectors

Non-concentrating collectors always have a specific collector area i.e. the area which faces solar radiation like absorber area for absorbing radiation. They are applicable in domestic water and space heating. Such collectors are further classified as follows:

I. Flat plate collectors
II. Evacuated tube collectors

b) Concentrating collector:

It concentrates the sun energy on a point or line so that high temperature will be achieved. These concentrators typically use for generating steam which is also needed for process application in industries. Concentrating collectors are also called as Imaging collector because makes reflection of sun at focal point or focal line by concentrating the incident rays approaching from sun. its types are:

- Parabolic Trough Collectors (PTC)
- Linear Fresnel Collectors (LFC)
- Heliostats
- Dish Sterling System(DSS)

2.1.2 Parabolic trough collectors

The parabolic trough collector is typically made by the special mirror or stainless steel surfaces bent in a parabolic shape. Its main purpose is to focus the sunlight on absorber tube passing through the centre of the trough. In the absorber tube, the fluid passing through will carry the heat gained from the solar flux as shown in figure 2.1. There temperature range lies between50ºC to 450ºC and has high collector efficiency depending upon the collecting area (aperture area).

Main working Principle of PTC is that it requires direct normal irradiation (DNI). The sunlight is reflected and focused by the parabolic mirror on the absorber tube which heats up the heat transfer fluid.

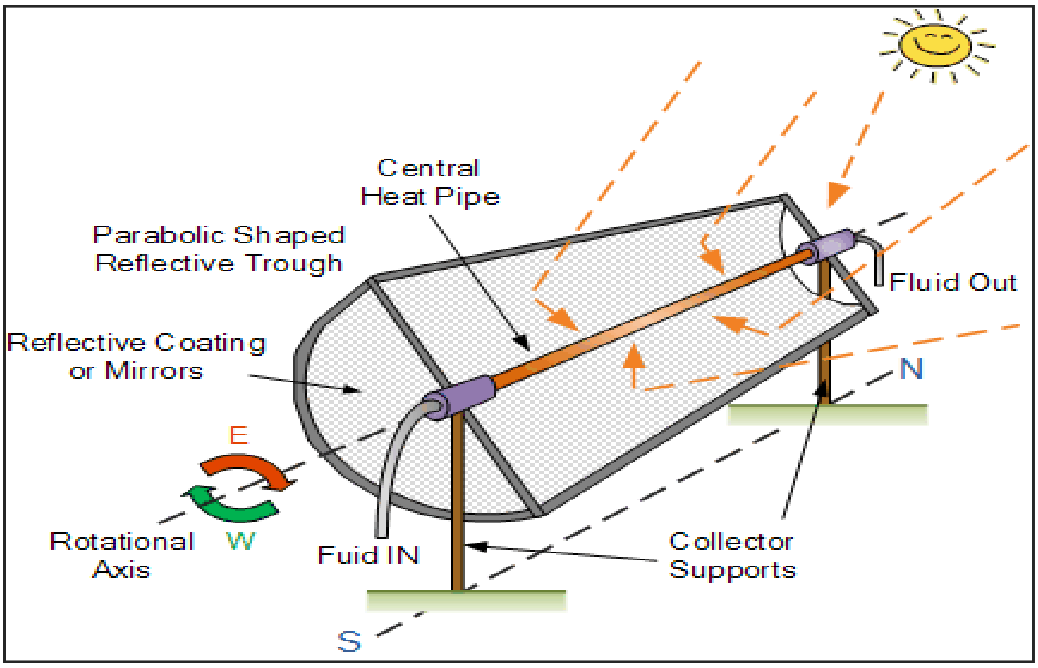


Fig. 2.1 The main components of Parabolic trough

2.1.2.1 Main features of PTC

- Operating temperature: 300°C to 500°C
- Concentration Factor: C=20–70
- Heat transfer fluid
    - Thermal oil, Water, Molten salt
- Typical power size: 50 to 400 MW
- Commercial projects commissioned
- Annual Efficiency = 12%- 14%
- LEC≈ 5ct/kWh

The Parabolic Trough Solar Collectors system will certainly play an important role to provide well-organized, cost-effective and environment friendly energy supply all around the world in next 5-10 years. Much work is being done on this technology throughout the world and especially in Pakistan. Odeh suggested the design, testing, assessment and advancing of an single-axis solar tracking parabolic trough collector for educational purpose that shows a standalone system to make process heat at reasonable temperature for demonstrative and instructional purposes. By making system track the efficiency of system moved up to 60% at noon. Solar tracking collector was intended as a self powered system and work remotely and separately under reasonable radiation levels. The system is tilt to a definite axis (N-S or E-W), it works constantly with nominal supervision. The simple design was used in which stainless steel act as a reflecting surface and a closed loop control system is for single solar tracking axis [1]. The study on the feasibility of a Parabolic Trough collector for distinctive sites of Pakistan. The solar resource is being verified besides the necessary insolation level. The most favorable potential site with appropriate irradiance level is recognized .Their projected design is confirmed with the assist of simulation. The designed plant will produce 31.54 MW on an regular day in June. The levelized electricity cost is initiate to be 15.47 cents per kWh. The capacity factor of the planned power plant is to be 20.5%. Cost evaluation with fossil fuel & renewable energy operational in Pakistan suggest that the projected PTSTP plant can contend well in the present energy market of the country [2]. They worked on mechanical design of parabolic trough, experimental testing for its use in generating electricity using steam engine. The theme of study is to focus the solar energy at any focal point produce suitable temperature. Temperature and Luminance is calculated for suggested design. Thermometer is used to measure temperature and luminance by LUX meter. Stainless steel used as a reflecting material which improve temperature but is not adequate for the steam generation. It can be replaced by some other reflecting materials like mirrors and aluminum foils [3]. They provide summary on the present cost, consistency and difficulties of using parabolic trough technology and suggested that it can be improve to great extent by the knowledge of the previously working plants. The thermal efficiency of the PTC can be improved by tracking the system from dusk to dawn. The main idea is to introduce the simple design of collector which can attain the high reflecting quality and tracking accuracy by existing cost efficient method in Pakistan. This will really decrease the cost of conventional power plant many solar technologies have been projected and are currently under testing phase for different applications in solar all over the world. The Parabolic Trough Solar Collectors system will certainly play an important role to provide well-organized, cost-effective and environment friendly energy supply around the world in next 5-10 years [4]. They compared performances of a Concentrating Solar-Trough plant of two different types having one-axis tracking system i.e. one with horizontal and other with tilted rotation axis. On the basis of simulations the statistical analysis of solar radiation data and efficiency has been calculated for both systems. Moreover, they analyze that the system with tilted rotation axis have yielded better results, comparable to those from horizontal sun tracking [5].

The investigational study examine effect on the thermal performance of compound parabolic concentrators using a sun tracking system. An electromechanical tracking CPC were considered and constructed for purpose of the examination and observed that the tracking CPC collector had 75% better performance than the similar fixed collector [6]. The numerical investigation of parabolic trough was performed by Cheng and Reddy. Numerical models are suggested for calculation of internal heat gain and loss with energy-efficient receiver because of natural convection. In order to check different geometrical parameters like thickness and flux intensity in different environments the thermal analysis of the receiver is carried out. The design with further modification on working fluids (water) and materials of the receiver (copper) could be checked for routine assessment [7, 8]. In this paper they enhanced the performance of parabolic trough by integrating tower collector which give a new way for using the solar energy more efficiently and cost-effectively [9]. Roberto Grena work on distribution of the energy absorbed by the receiver surface by taking the help of simulation which calculate the optical efficiency [10].

Summary

The literature review related to the topic is being carried out in which the main focus was on the paper describing the feasibility of solar all around the world. In Pakistan a lot of encouraging work is being done in order to promote the use of parabolic trough specially the industries, which are the main focus of the researcher is to benefit them by this free of cost energy. The paper above explains the overall scenario for the parabolic trough collector whether it’s designing, installing, testing or developing. The benefits of introducing tracking system is specially discussed that how much the improvement in efficiency can take place by it.

References

[1].Odeh, S.D. and H.I. Abu-Mulaweh, Design and development of an educational solar tracking parabolic trough collector system. Global Journal of Engineering Education, 2013. 15(1).

[2].Engr. Shahrukh Saleem, P.D.A.u.A., Analysis & Design of Parabolic Trough Solar Thermal Power Plant for Typical Sites of Pakistan. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), May – Jun. 2014. 9(3).

[3].Iqbal, S., et al. Design, fabrication and analysis of solar parabolic trough collector for steam engine. in Robotics and Emerging Allied Technologies in Engineering (iCREATE), 2014 International Conference on. 2014. IEEE.

[4].Raja, N.K., et al., Design and Manufacturing of Parabolic Trough Solar Collector System for a Developing Country Pakistan. Journal of American Science, 2011..

[5].Dicorato, M., et al. One-axis tracking optimization of Concentrating Solar Power plant for electricity production. in Universities Power Engineering Conference (UPEC), 2010 45th International. 2010. IEEE.

[6].Khalifa, A.-J.N. and S.S. Al-Mutawalli, Effect of two-axis sun tracking on the performance of compound parabolic concentrators. Energy Conversion and Management, 1998. 39(10): p. 1073-1079.

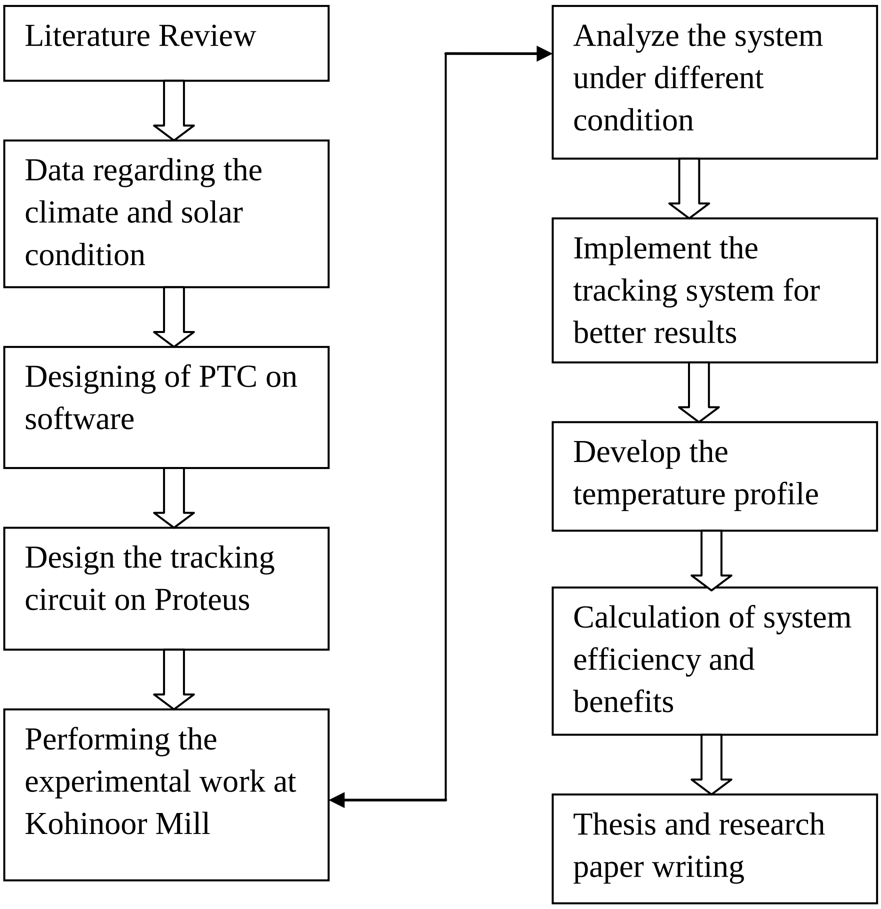
[7].Cheng, Z., et al., Three-dimensional numerical study of heat transfer characteristics in the receiver tube of parabolic trough solar collector. International Communications in Heat and Mass Transfer, 2010: p. 782-787.

[8].Reddy, K., K.R. Kumar, and G. Satyanarayana, Numerical investigation of energy-efficient receiver for solar parabolic trough concentrator. Heat Transfer Engineering, 2008. 29(11): p. 961-972.

[9].Han, W., et al., Performance Enhancement of a Solar Trough Power Plant by Integrating Tower Collectors. Energy Procedia, 2014. 49: p. 1391-1399.

[10].Grena, R., Optical simulation of a parabolic solar trough collector. International Journal of Sustainable Energy, 2010. 29(1): p. 19-36.

Flow Chart



Literature Review
Data regarding the climate and solar condition
Designing of PTC on software
Design the tracking circuit on Proteus
Performing the experimental work at Kohinoor Mill
Analyze the system under different condition
Implement the tracking system for better results
Develop the temperature profile
Calculation of system efficiency and benefits
Thesis and research paper writing

Chapter 3

REVIEW ON EXPRIMENTATION AND CHARACTERIZATION METHOODS

After completing the literature review I have to check the different options available and the methods which are the most suitable one. In this search have to go through the different method on which the work is done by the other people and are interlinked with my work. Specially in a case when you have to perform a practical work, take great care of each and every aspect to make the design a best example for others. Thorough study of the other different methods is done before implementation of what you have at the back of your mind.

The main focus of my study is on the design and tracking of the parabolic trough collector. For both the things you have to take great care of different parameter which will be discussed in the lateral part. A manual method is introduced to create high efficiency solar collectors adjacent to very low cost, which mainly suited for research and demonstration purposes.

3.1 Working principle of PTC

Parabolic trough solar collector is made by a concentrator of a parabolic cylinder shaped. Which reflect and focus sun radiations at a receiver tube positioned at the focus line of the parabolic trough. The receiver used the incoming radiations and converts it into thermal energy, after that transfers to fluid medium moving within the receiver tube. Such method of concentrated solar collection had the benefit of high efficiency and low cost, which could also help for thermal energy gathering, for producing electricity or for both, therefore it is an important way to exploit solar energy directly.

3.2 Analysis of Concentrator

In the analysis of concentrators it is important to distinguish between imaging and non-imaging systems. Non-imaging only requires that all rays entering the entrance aperture leave the exit aperture somewhere. It may be not surprising, that the fewer constraints of non-imaging systems lead to a more higher flexibility concerning the concentrator design so that higher concentration ratios can be achieved.

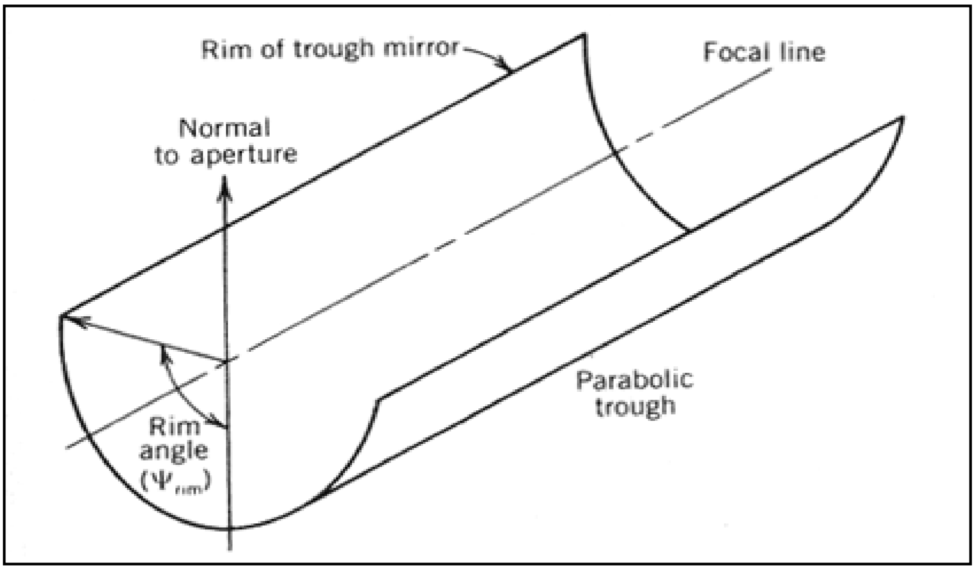


Fig. 3. 1Compound parabolic concentrator[1]

In this example a truncated cone with reflective inner surfaces, where the radiation enters through the larger opening and leaves through the smaller one. A very efficient design of non-imaging concentrator is cone with a specific shape forming a segment of parabola. Such a concentrator is called compound parabolic concentrator design can approach theoretical concentration limit closely. The conservation of the Etendue implies that for a given ratio of exit to entrance apertures of the CPC, only rays in a cone with an half angle of will be accepted by the concentrator.

3.3 Different methods of design

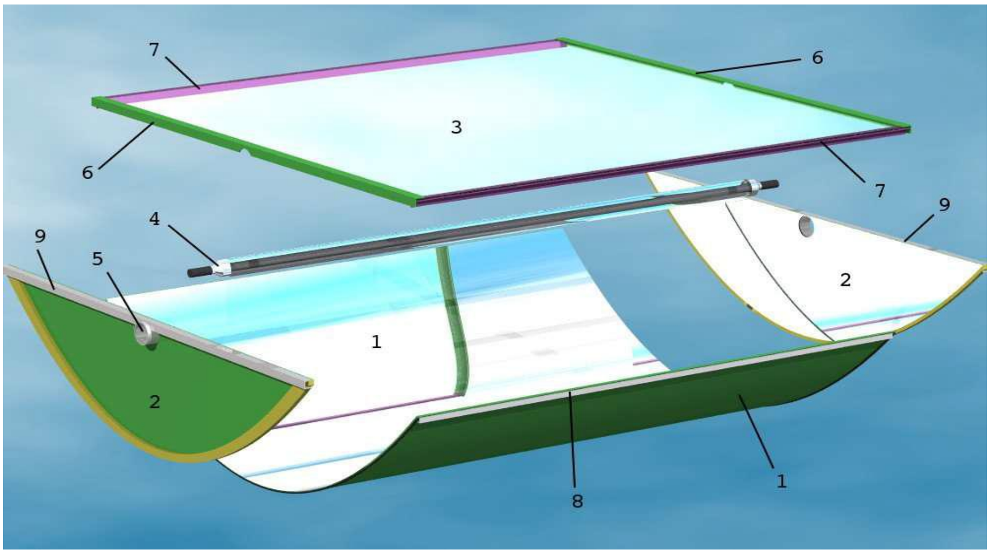


Fig. 3. 2 Different parts which are being made by manual method

There are many methods to figure the parabolic cylinder reflective surface having any of formation a curved plate in high temperature. But such methods are luxurious and have difficulties to attain a high precision. Figure 3.2 below showing the different parts which are being made by manual drawing method.

Its each and every part is made by a specific dimension which is being calculated by using any software or mathematical calculation by your own self. In our case we have use the parabolic calculator.

The parabolic calculator plan solar collector using parabolic reflectors. If we want to design a solar trough, this software calculates the focal length and (x, y) coordinates for a parabola of any diameter and depth shown in figure 3.3. It can assist you to verify the size and shape of your parabola.

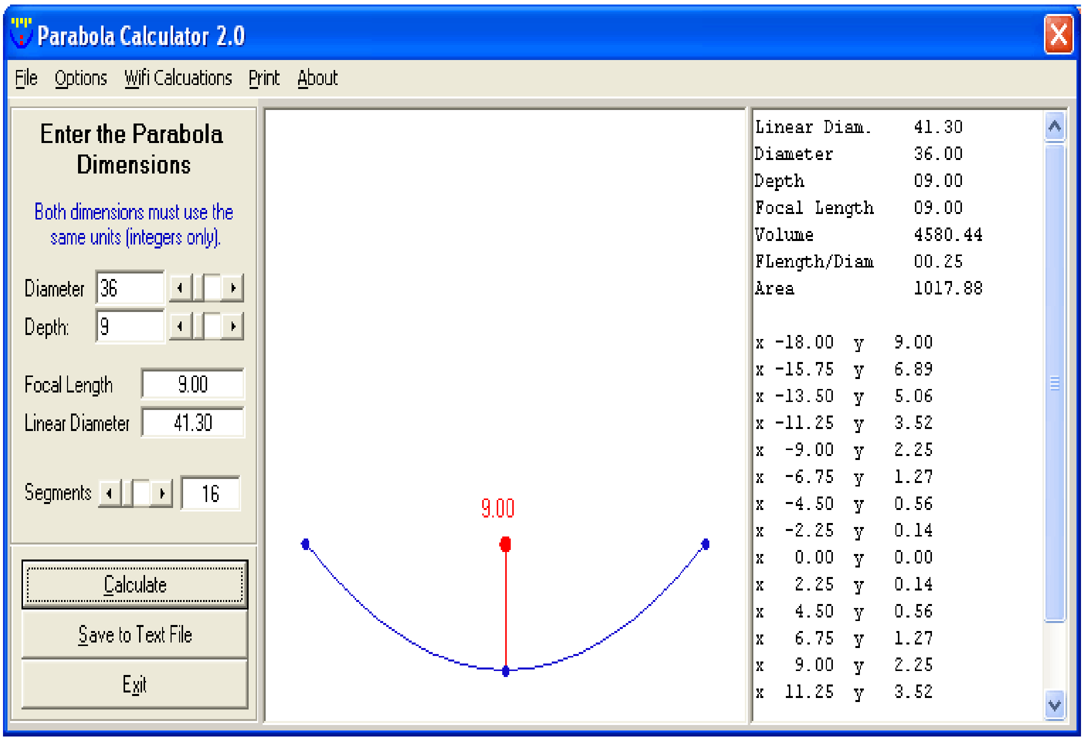


Fig. 3. 3 The general calculation performed by parabolic calculator

In figure 5 the calculation of another case is being performed in which the initial dimension of the design which we are aiming to made was given and the according to that dimension the calculation is being performed in which different equation are used. To calculate the diameter, focus, depth etc. It help us in making our parabolic trough.

The Equation for a Parabola is:

$y^2 = 4ax$..(3.1)

$y = a(x^2) + b(x) + c$...(3.2)

$\text{Volume} = (\pi \times (\text{ diameter}/2)^2 \times \text{height})/2$.........(3.3)

$\text{directrix} \Rightarrow y = c - (\text{b}2 + 1)4\text{a}$......................(3.4)

The focus of PTC is very important if it is not being properly checked before making then your total PTC will be of no use. the different methods are being used to check the focus like laser pointing, pin whole method, trace focus line by the segment etc. A laser pointer is used for checking the real shape accuracy of any reflector. Some troughs aren't parabolic. So by orthogonal (perpendicular) mounting of the laser pointer to point directly into the trough and focusing the laser along a rigid support, one can simulate parallel rays entering the dish. These can be reflected off the back of the dish and the focus movement may be observed [2].

The concentration ratio is the actually the ratio between collector aperture area and the total area of the absorber tube shown in equation. Its value mostly lies between 20 and 70. It actually represents the reflector quality. A higher concentration ratio allows the collector to reach higher temperature with minimum losses [3].

$\text{C} = \text{I}^{\circ}/\pi \times \text{D}^{\circ}$..(3.5)

I°= parabola width. D°=outer diameter of absorber pipe

3.4 Methods to visualize the design

Now to visualize the design we must need software, which show the real picture or drawing of the design we are aiming. The different software are used for this purpose like:

QCAD: This software is used to sketch the two dimension objects. While using its really easy and reliable and deal with all type of technical drawing.

Google Sketch up: This is really famous software among students and professionals because it's easy to use so it's adapted as a substitute for design.

Draft sight: It is basically used to make, revise and view all types of drawing of al format and becoming popular in students, professionals and teachers.

BRL-CAD: Its main applications are to examine the solid model system by focusing on the different parameters like interactive geometry editing, image and signal-processing tools.

Archimedes: The complex compound 3D shapes are made on it which are difficult o visualize by other software.. It is famous for being one of the most functional drawing software.

But in our case the AutoCAD which is basically used to sketch 2D and 3D drawings by the people of different disciplines, particularly in industries such as architecture, interior design and engineering. AutoCAD is the most usable software in the industry because of easily availability and the perfection in design. The figure 3.4 represents the actual model of the parabolic trough made on AutoCAD.

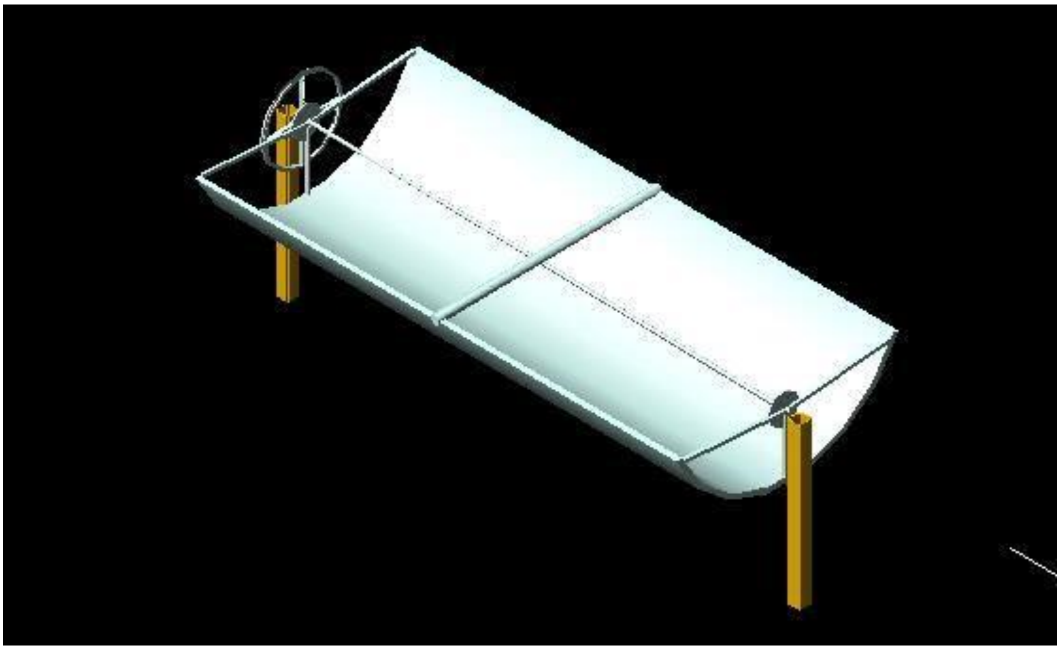


Fig. 3. 4 The general drawing on AUTOCAD

3.5 Solar Tracking Methods

The tracking methods are usually characterize in two categories.

- active using a closed loop
- passive, with an open-loop

3.5.1 Active Tracking

In active tracking method the light sensitive sensors are used to check the position of sun and align the system in a very lively way to the best position. The sensitivity of the sensors and its decision making for the system is limited in such type. The unnecessary movement in the "search for sun" by the tracker in cloudy conditions can be expected, which causes increase in power consumption and mechanical wear. The accuracy range of active tracking system is from 0.2 to numerous degrees. By this method the solar devices show great difference in efficiency with tracking precision and active methods are of relatively low technical difficulty, hence are more useful. The selection of a tracking method is the concern of every solar tracking advance process. The choice of passive or active method ought to be use. It can be depend on information of system accuracy necessities. The main factors affecting the whole decision method for design and use solar tracker are the system accuracy requirement and the accuracy limits of the tracking method. We are using the active tracking in our system as the highly sensitive LDR sensor are used which track the sun all the day. The figure 3.5 represents the active system.

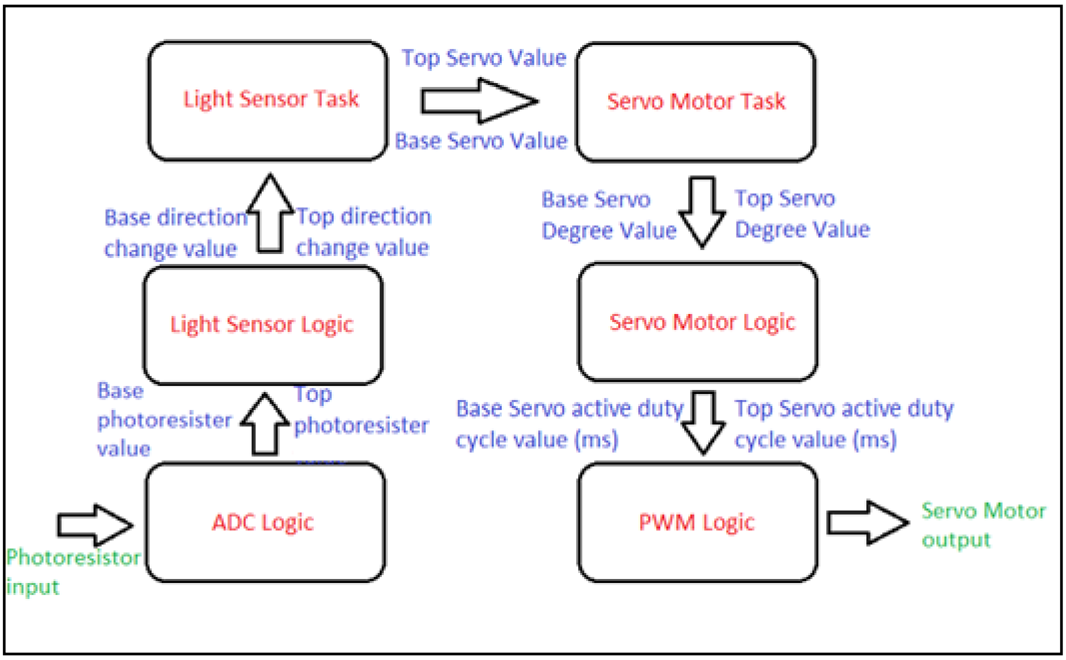


Fig. 3. 5 The Active system

This tracker is cost-effective, easily available and flexible. The condition flexible was reasonable by the reality that system should able to survive mechanical wear and loads. It had to be made, so that it was easy to accumulate/disassemble, adjust and use for work.

The system had to be cost-effective due to the economic limitations upon the project. In fact, if it is economical play an important role in system development, as they do in any evolution process. The habit of a solar tracking testing equipment is necessary. This type of system needs to work with special logic algorithms and motor control techniques. The different software are used to construct the electronic circuit like work bench, circuit lab, circuit maker etc but me using proteus for designing of tracker circuit.

3.5.2 Passive Tracking

Passive tracking methods use open loop in order to calculate the solar position in the specific interval which is programmed and then provide the command to move. The more chances of error is caused in this type of strategy if no response of the relative position of the tracker is provided in every instant, But is limited in accuracy only by the precision of the algorithms, which explain that electro-mechanic accuracy is ideal. The azimuth axis vertical and zenith horizontal position is of vital importance in such type for the generally tracking accuracy [4]. Passive tracking is the technique of selection when the high precision is demanded for solar installation shown in figure 3.6.

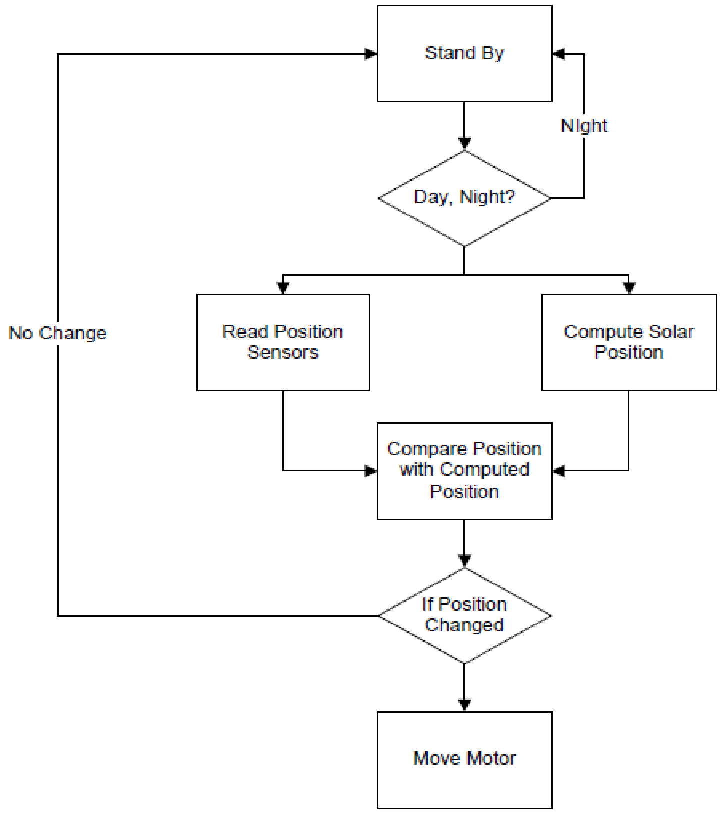


Fig. 3. 6 The Passive System

3.6 Heat exchanger model

After checking the above given methodology the system is practically designed according to specifications. The trough is checked in different ways, whether it's related to tracking or weather condition. The heat exchanger model can be design on different software like mat lab, simulink, cfd etc. The Saleem et al performed an experiment in which after getting the experimental data for the increase in temperature of concentrator heat exchanger model was simulated using COMSOL to attain the outcome for the temperature of the hot water [5]. COMSOL is a simulation software package for various physics and engineering applications. we can model and simulate any physics based system on it. The model furnishes you with simulation tools to study the mechanism of heat transfer. So by getting idea from there I have also made the heat exchanger model to verify the heat transfer at different points by collector shown in figure 3.7.

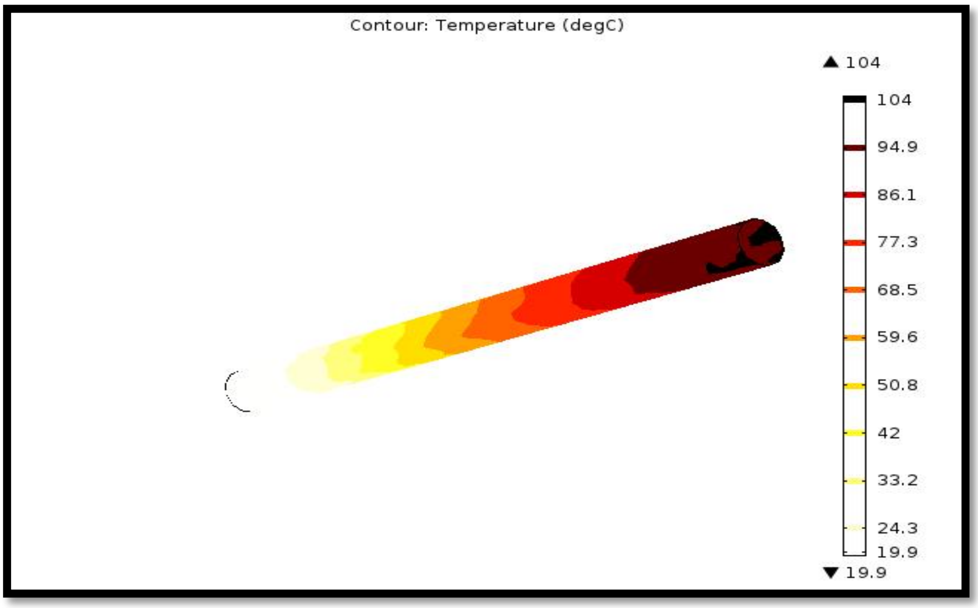


Fig. 3. 7 The COMSOL model

Summary

In this section the overall methodology of the experimentation process is discussed. For that we have to check different relevant methodologies and compare method with other discussed above to get more appropriate method to remove the inefficiencies from the selected one. The special consideration was given to the design and tracking principle which were our main focus. After checking the above methodology the system to be practically designed according to specifications. The trough will be checked in different ways, rather its related to tracking or weather condition. The result was confirmed by performing experimentation in a practical way and also reconfirm by using software like COMSOL. This is used to check the increase in temperature at different point by making of heat transfer model.

References

[1].Pitz-Paal, R., High temperature solar concentrators. Solar Energy Conversion and Photoenergy Systems, 2007.

[2].Oo, L.L. and N.K. Hlaing, Microcontroller-Based Two-Axis Solar Tracking System. 2010: p. 436-440.

[3].Zarza, E., Medium Temperature Solar Concentrators (Parabolic-Troughs Collectors). Solar Energy Conversion and Photoenergy Systems, 2005. 1.

[4].Petrov, L., General formula for on-axis sun-tracking system and its application in improving tracking accuracy of a solar collector. Solar Tracking Strategies, 2009: p. 298-305.

[5].Saleem, U., M.A. Hanif, and A. Waqas, Alternate method for steam generation and hot water in Textile and Leather Industry using Solar Thermal Technology. 2014.

Chapter 4

EXPERIMENTAL WORK PRFORMED

After completing literature review and discussing about alternative methodologies available for parabolic trough collector (PTC).Now focusing on the parabolic trough collector and search the place where to perform experimental work.

It is a fortune or a luck that on these days the energy development board (EDB), were about to install their first ever project of Pakistan on parabolic trough collector at Kohinoor mill, Islamabad. Truly speaking that the main motivation of mine behind my thesis topic was also this project. So, with the help of my supervisor I got a chance to work on this project and perform all my experimental work at Kohinoor mill Islamabad, their I got a chance for the designing, fabrication, development, installation and testing of 50 parabolic trough collectors and also made the one prototype for the university which is used for the demonstration and is installed in solar park of centre for energy system, NUST.

Fig. 4. 1 The system installed at solar park

During the experimental work had faced the different problems and move to alternative options which all are the part of the experimental work performed.

4.1 Area/ Site of installation

The first challenge was the selection of suitable area for work at Kohinoor mill as the multiple activities are performed there. So, have to select the place which is suitable from the industry point of view and the flexible for installing in all manners. As the hot water main need was at in processing department. So area given was on the roof of processing building as it is the nearest place to the boiler where hot water is to feed and because as much move far our cost will increase(in term of insulation, pipe) and also cause the temperature losses.

The face of the building in which it is design is not align to the position of the sun path. Have to provide a bit tilt angle to our system to get the sun rays for the maximum time of the day. The 15 degree tilt was provided in the vertical angles away from the poles, which will also be helpful to us in winter as the sun changes its position in winter. Secondly the main use of the system will be specially in winter when there is shed off of the factory due to the no gas supply. Hence, it was install in east west position and towards the south facing in order to follow the right trajectory of the sun.

The area on the roof was in square shape. But have to keep a bit tilt to follow the sun trajectory. The initial calculation done by the person for the installation of 50 trough according to the area of trough which will be install in straight line back to back and told that they can be install in one part of the roof, but according to the condition have to use the three parts of the roof, So while installing in initial visit of the site this thing specially have to be kept in mind. Otherwise can face a serious problem at eleventh hour.

One of the most important thing is shadow, the place was surrounded by the huge building from one side which is creating its full shadow till the peak time on the one side of the roof, which can waste the almost 2 to 3 hours of sun light of every day if the trough are install into that part. we have checked that place by partially fixing one of our trough at that side and observe that the light will reach the upper part of the trough after 10am which means it will waste our 3 to 4 hours of sunshine of early morning time period and even cover all the trough after 1 hour almost at peak time. So decided to install the trough far way leaving that area just behind the building and providing tilt angle shown in figure 4.2. The shadow must be kept in mind to get the maximum use of sun otherwise it will really harm the overall efficiency of the system.

Fig. 4. 2 Showing the building creating the shadow

According to the area the we have to install 50 troughs so have set them in a different array setting.

Table 4. 1 Showing the array structure in which trough are installed

1st part	2,4,4,4,2
2nd part	2,6,6,4,2
3rd part	2,3,4,3,2,2

While making these arrays keep the troughs align, always have to keep them back to back in the rows and straight in a column as well shown in figure 4.3. If it's not done in such a manner, then major problem can take place like at the time of sunset or sun rise when the sun rays have to come almost parallel to the top of the troughs. The troughs in the first row will block the path of the path of the sunrays which are reaching to the tracker of the behind one. Hence the tracker will not sense the light and the trough behind will not move and get use of the early morning time similarly at the time of sunset the last one will also do the same which reset the trough earlier. also came a case across in which one row of our system become misalign and block the path of the sunlight coming from behind. In this condition all the dishes in the next row their tracker did not detect light and revert the dishes to the position of the sun rise. So the system synchronization is very important for that the special work is done on tracker which will be discuss latter.

Fig. 4. 3 The array setting of the trough

4.2 Designing Of Parabolic Trough Collector

A prototype of single axis parabolic trough collector is designed to get hot water at ambient condition. The system mainly consists of 4 parts; parabolic trough reflector, a receiving tube, or pipe, motors and gear mechanism , tracking system.

4.2.1 Parabolic trough reflector:

Specification:

Table 4. 2 The important specification of trough

Length	3.65m
Width	1.6256m
Weight	65kg
Height or depth	0.515m
Area	$6m^2$

A highly polished stainless steel sheet of grade 304(26SwG) is used as a reflecting surface It has the reflectance of about 0.80.Depending on the reflecting area a very high temperature can be attained .The sheet is fixed on the frame made by the 7 length of stainless steel pipe of 5mm arrange in parabolic shape having the rim angle of 74˚. These systems are meant to focus beam of radiation to the receiver shown in figure 4.4. Therefore, the focus of the trough should be correct and the parabolic curve able to focus all the rays at focus point which in 3-D called as focal line shown in figure 4.5.

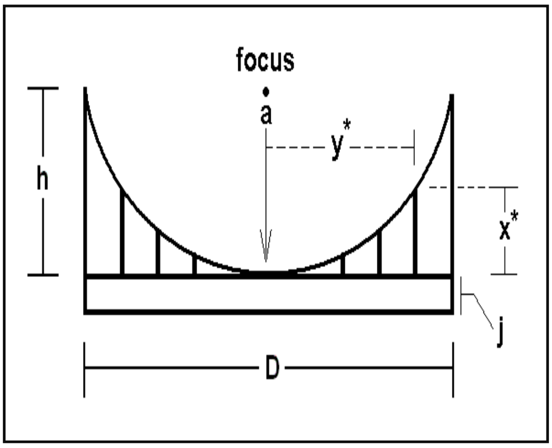


Fig. 4. 4 Focus and other parameters   Fig. 4. 5 The pipe at full focus in real

$y^2 = 4ax$..(4.1)

As, $y = D/2$, $h=x$

$a = D^2/16h$,   a=12 inches or 1feet................(4.2)

Using the equations and by using geometry angle its diagram is made manually first to confirm its angles shown in figure 4.6.

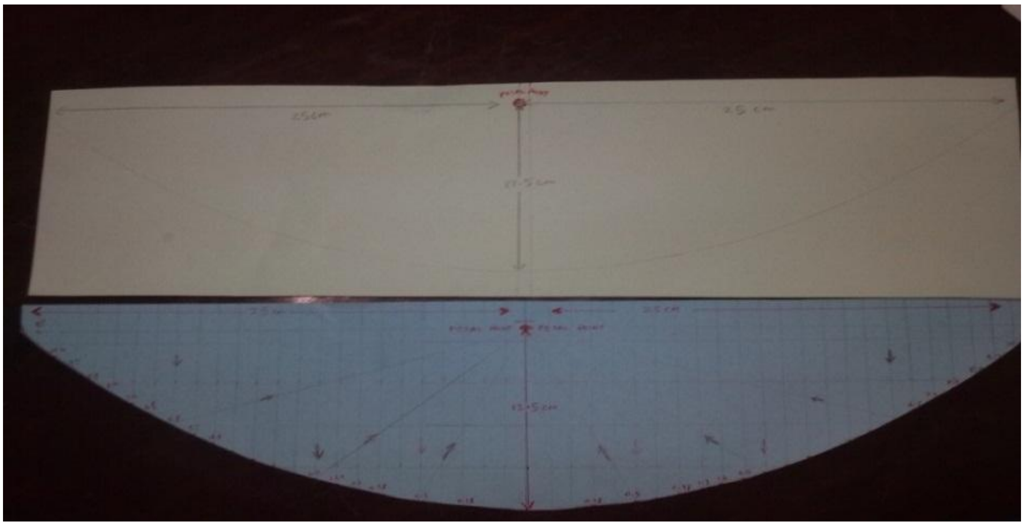


Fig. 4. 6 Manual drawing made in first phase of designing

Then to verify the design with the help of software, this software calculates the focal length and (x, y) coordinates for a parabola of any diameter and depth. It can assist you to verify the size and shape of your parabola shown in figure 4.7. The result of parabolic calculator are shown in result and discussion .

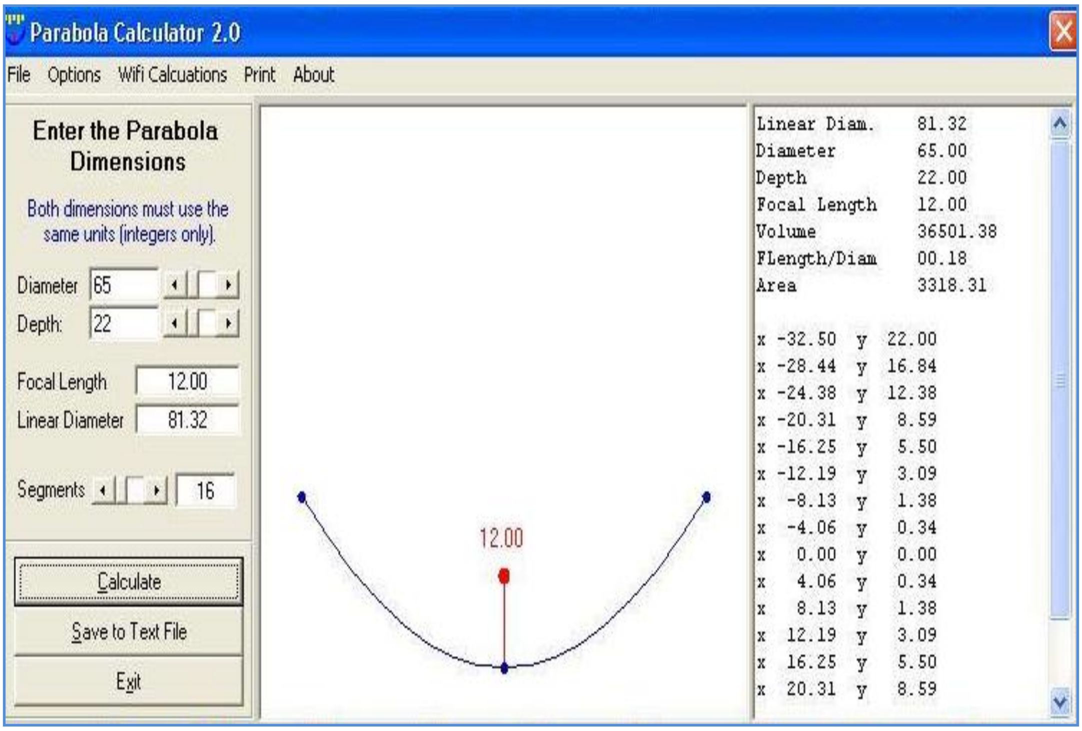


Fig. 4. 7 The parabolic calculator

The 3D model on AUTOCAD was also being made which is shown in result portion. AutoCAD which is basically used to sketch a 2D and 3D drawings by the people of different disciplines, particularly in industries such as architecture, interior design and engineering. The concentration ratio is the actually the ratio between collector aperture area and the total area of the absorber tube shown in equation. Its value mostly lies about 20 and can reach up to 70. It actually relates the reflector quality. A higher concentration ratio allows the collector to reach higher temperature with minimum losses [8].

$C = I^{\circ}/\pi * D^{\circ}$, $C = 20.38$.......................................(4.3)

I°= parabola width , D°=outer diameter of absorber pipe

Before making the trough all the troughs have been checked and universal design is followed for all of them. The interspacing between the 2 trough in a column or back to back is kept 10 feet. It has to be kept always kept equal to or greater than 10 feet as calculated according to the size of trough ,if kept less than the shadow of one dish will be created on the other which make many of the segment not receive the light cold done by the wind blowing through it and decrease the efficiency of the trough as shown in figure 4.8.

Fig. 4. 8 The specific spacing between back to back trough to avoid shadow

The spacing between the two troughs side to side in a row is kept 12.5 feet. this is also a design parameter .Should be always remain equal to it so that the tough ball bearing can easily settle on the half hook in and half out to create stiffness while swinging of the trough.

The trough is hanged on the two pillar of steel having height of 1.22m. It is always kept nearer to the surface because the wind pressure exerted on the trough will be less near the surface. The stand of the trough should be kept very strong. It should be able bear the weight of the trough in extreme condition. For this drill the surface to 5-6 inch down and fix it with the help of 6 inch long catchers to make the pillar stiff on the surface. But we were unfortunately the surface was of mud and sand from the top about 8 inches, So now we have make a concrete block of 1*1 size and having 8 inch height, fix the stand on the block and dig a 2*2 area where we put these block according to the measurements and spacing and covered it fully by concrete shown in figure 4.9. The stands which are connected in a array must have the same level. So that the water can easily move from one end to another which can be blocked at any point if the height is greater at that part. The big pulley is connected to the trough which is connected with the motors through belt which help the trough in moving.

Fig. 4. 9 The stand on which trough is hanged fixed and level by concrete

4.2.2 Receiver Tube

Fig. 4. 10 The copper tube used as a receiver

It is one of the most important parts of the system. From here the liquid will pass which collects the heat hot exchanging heat from the pipe. It basically acts as a heat exchanger which gets heat from sun rays and transfers it to the fluid passing through it. The width of the receiver is estimated from the width of solar flux pattern in focal line. The different options can be used as a receiver like vacuum tube, copper tube, steel pipe having a coating of absorber material etc depending upon the usage and budget.

In our case Cu tube is use of 1 inch diameter and 12.5 feet long passing from the centre of the trough from the focus line as shown in figure 19, well supported by the ball bearings and Teflon rings. The pair of trough in a row is interlink with each other by joining their pipe with gas welding which is the finest of all and remove the chances of any sort of leakage or loss of heat. The pipe should be at its focus line which is calculated above to get the maximum efficiency. Because if our focus is at its correct position the rays after falling on to the segments will converge to the pipe all the time as shown in figure 4.11.

Fig. 4. 11 The receiver tube of parabolic trough at its full focus

A laser pointer is used for checking the real shape accuracy of any reflector. Some trough aren't parabolic. So by orthogonal (perpendicular) mounting of the laser pointer to point directly into the trough and focusing the laser along a rigid support, one can simulate parallel rays entering the dish. These can be reflected off the back of the dish and the focus movement may be observed. This idea was taken from a paper which was practically checked [1].

The pipe will be connected to the inlet of the Cu tube from where the water is feed and collects from the other end. The pump is used to maintain the flow of water by providing an external force. The pump of high rating is to be connected as we have to move the water through the 50 troughs which are connected with each other. As trough are split into 3 segment the piping between the all segments is very important. The pipes should be properly insulated by the special insulating material. this work is done with special care and expertise because if left uncover will be cool down by the air passing through it specially in winter the pipes should be insulated like a vacuum, so that the external conditions would not affect the temperature.

While testing we have calculated the temperature at different points of Cu tube by connecting different thermocouple to get the variation of temperature. The inlet and outlet temperature of water is also measured. While measuring temperature we have seen a difference between the surface temperature and the temperature of the water. This is due to the air passing by the outer side make it cool down and losing in temperature which can be improve by introducing vacuum tube. While transferring heat the different type of losses take place [2].

Losses=convection + radiation + conduction.........................(4.4)

Among them the main loss is convection which is due to the external environment effect involves differ parameter like wind speed cooling the pipe, outer temperature, humidity etc. The radiation losses is due to the coating our outer surface of the pipe and the conduction losses are done through the brackets which hold the tube .The supporting rings of tube are made of Teflon, which can survive up to 150 to 200˚C. They are used to keep the pipe fix at the focal line. While working we have seen a very interesting result when our Teflon ring is melted due to a very high temperature of Cu tube shown in figure 4.12.

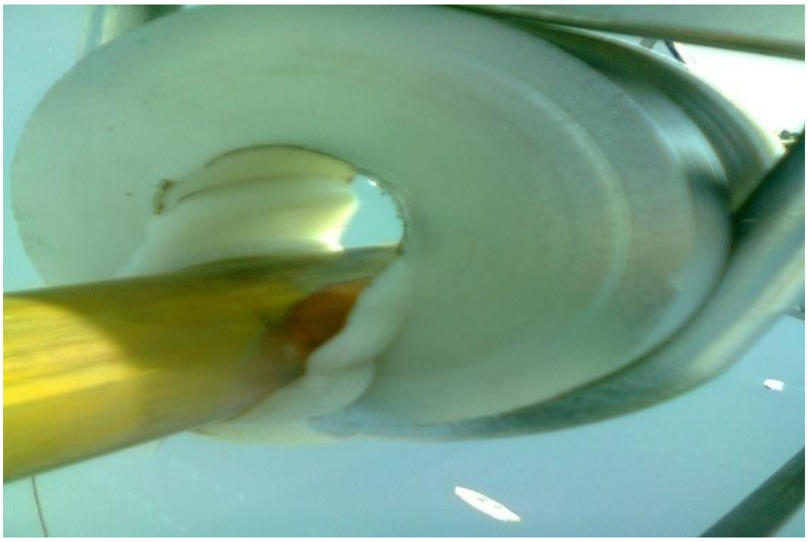


Fig. 4. 12 The melted Teflon ring due to very high temperature

At that instant the temperature of hot water vapors or steam which was inside the cu tube was almost 260˚C shown in figure 22, due to the continuous focus and no water was passing through it on the little which was stuck with its inner wall. The thermocouple are used for the measuring of temperature.

Fig. 4. 13 The temperature at instant when Teflon got melt

4.2.3 Motors and Gear Mechanism

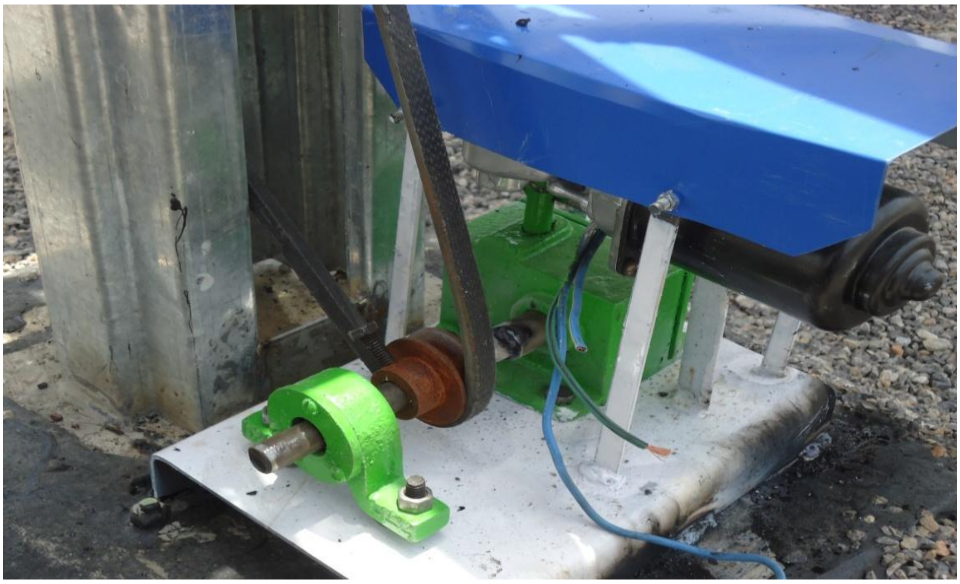


Fig. 4. 14 The motor and gear mechanism of the system

The motor helps the trough to align with the sun for maximum time as guided by the tracker. It is connected with the trough by the pulleys and belts shown in figure 23.The12V DC motor has been used which has the sufficient torque to move the trough of weight 65 kg. The electrical specifications of motor are shown in Table 4.3.

Table 4.3 The electrical specification of motor[3]

Nominal voltage	Nominal power	No load current	Stall current	No load speed(rpm)	Stall torque
12V	150W	2.5-4.5A	65A	15-40	95Nm

The motor will not be under continuous use all the time. The tracker will control it and switch it on after the delay of every 30 seconds .The trough will move up to certain degree as commanded by the tracker. In order to move the trough or hold it on a fixed place the motor has very interesting role. The motor is supplied 12 V DC by an external source which can be a battery or using AC to DC converter which can convert the 220 V AC to 12 V DC. As, we are using tracking system so the tracker is the brain behind which is controlling the movement of the motor. The motor and the supported structure added with it help to increase the efficiency by getting maximum sun rays throughout the day. By holding the trough at its position helps to align it with sun and safe the system in extreme weather condition.

While working on the field we have to test different type of motors by checking their V and I values, power rating on load and off load etc to select the best one shown in figure 4.15.

Fig. 4. 15 Testing of motor at offload with respect to tracker

While testing it have to pass through the many interesting situations where the motor burn due to overload because the specification and material inside was not of that quality which was embossed on its plate. Some motors even not able to provide the much torque which is needed for that load. In one case because of continuous use of motor heats it up, so we have to provide delay in motor working which is done by the tracker.

The motor is connected with the gear assembly which shifts the electrical torque to the mechanical torque. The gear we are using has the gear ratio of 1:3. The two gears are interconnected with each other one is called verm gear and other the load gear. When the motor is magnetized the rotor which is connecting the motor and gear will move the gear which is horizontally connected to one step, at that time the other gear moves its three steps. When the motor stops moving the both the gears just locked each other in a way that whole structure will get jam. The figure 4.16 represents the internal structure of gear.

Fig. 4. 16 The gear internal structure

There hold is too much strong that can bear the extreme condition until their teeth will break or got slipped because of extreme force applied. One such incident occur wile testing that our gear got slipped because of the material of which gear is made was not so effective .So we move forward to another in which both the gears are made of good quality of solid iron. The gears assembly is kept safe in its gear box which is a metal case box to keep it safe from corrosion and has to be grease or oil after some time.

As, the rated torque of the motor is above 35 rpm but the required speed is quite less than that, so the gear mechanism is really helpful, to move the trough up to 0.25˚ after every 30second. while testing one condition come in which the air pressure was very high so because of huge weight body of the trough there was a strong chances that it will be damage badly but luckily that time it survive but make us think to do something for such worse condition. The brakes are also applied to the system which holds it up in condition when the gear got slipped or any other difficulty especially in extreme condition shown in figure 4.17. These things not only increase the efficiency of the system but also protect the trough in extreme condition like from high wind pressure and misalignment under different condition etc.

Fig. 4. 17 The brake mechanism applied to the trough

4.2.4 Tracker

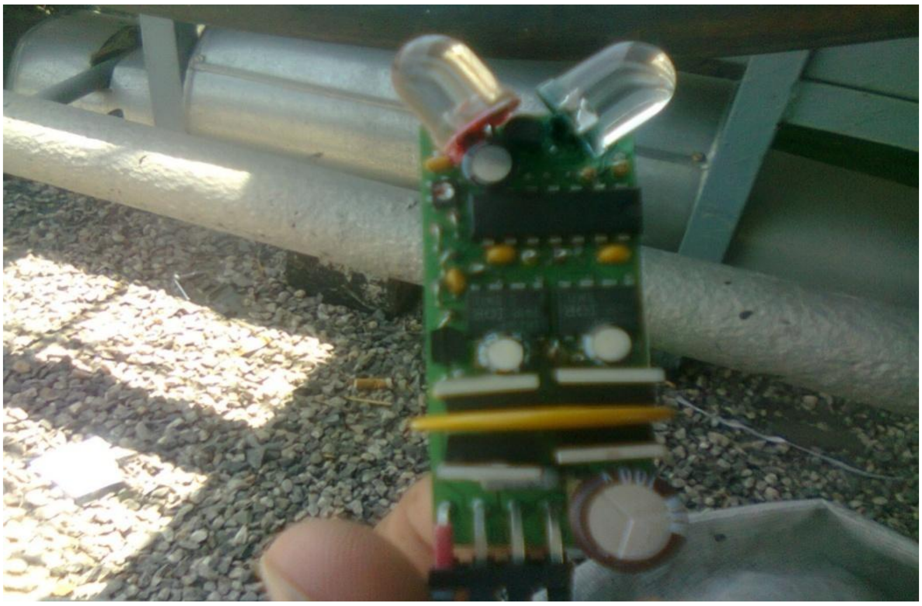


Fig. 4. 18 The tracker used in the project

A simple and accurate single axis electronic solar tracker is being used for the tracking purpose. It has pair of green LED's which are working as photovoltaic sensors shown in figure 4.18. As the sensor detects the light, voltage is allowed to pass through the circuit by the remote which develop the high signal across the MOSFET. Now the whole circuit will start operation as the value of voltage passing is greater than the terminal voltage Operational principle of traditional analogue sun sensor is same as of modern era [4].

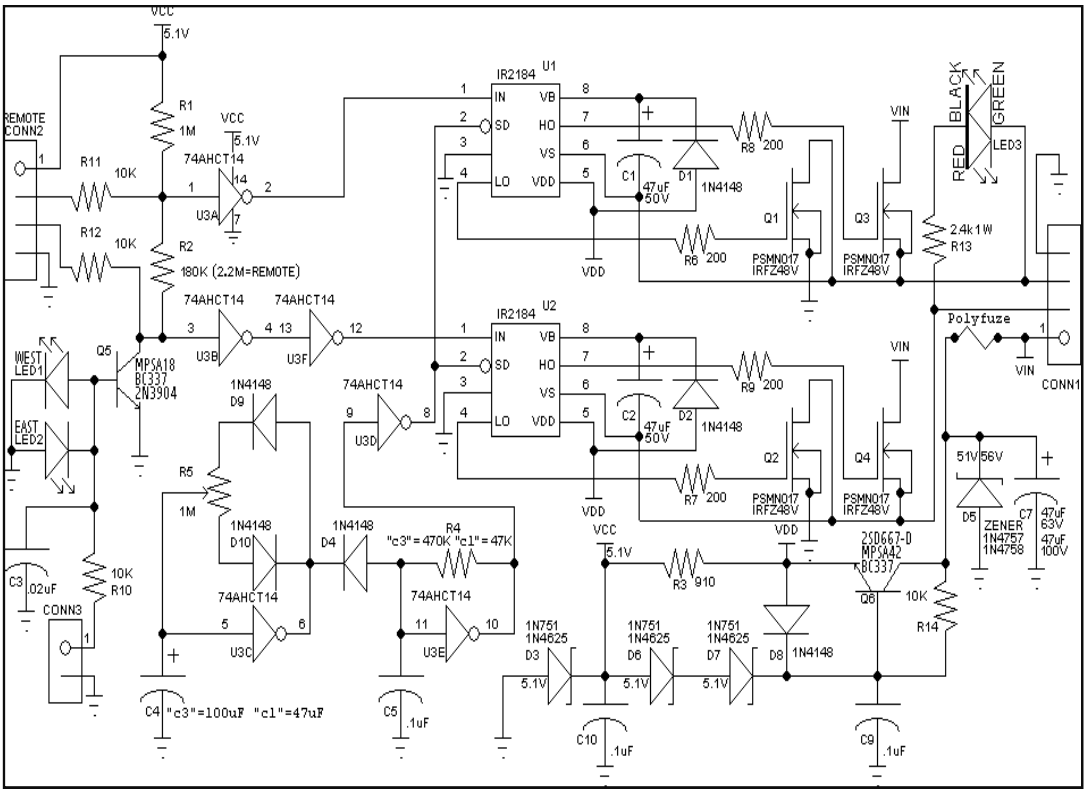


Fig. 4. 19 The circuit diagram of the tracker

The active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum [5]. The figure 4.19 represents the circuit diagram of tracker. The variable resistor is present to adjust the duty cycle from 0% to 100%, cycle time in our case is set at 30 seconds. The protection from over current, protection is done using fuse in the circuit. Whose limit is up to 3.75A. For reset the power can also be removing to make it cool down.

The current should not exceed too much that it cross its limit because of it the drivers can be damaged and caused a short circuit. In case if driver started getting warm remove the power immediately. The test for the under voltage condition is performed in which the voltage is drop to less than 10 volts and observe that the indicator LED has gone out. In order to verify the above circuit its first constructed on the proteus to check the response at every step as shown in figure 4.20. Similarly for the over temperature condition the MOSFET is thermally coupled with fuse to the transistor. The board has also enough spacing to reduce the tendency of short. The wide operating voltage range from 10.5V to 44V to protect MOSFET and the power source. The reset option is also present in the circuit to retain its initial setting if any problems occur. These new LED sensor have a really quick response and even detect the U.V rays. In particular, a model to estimate solar radiation on a sun-tracking surface is developed, in order to minimize the angle of incidence and thus maximize the incident beam [6].

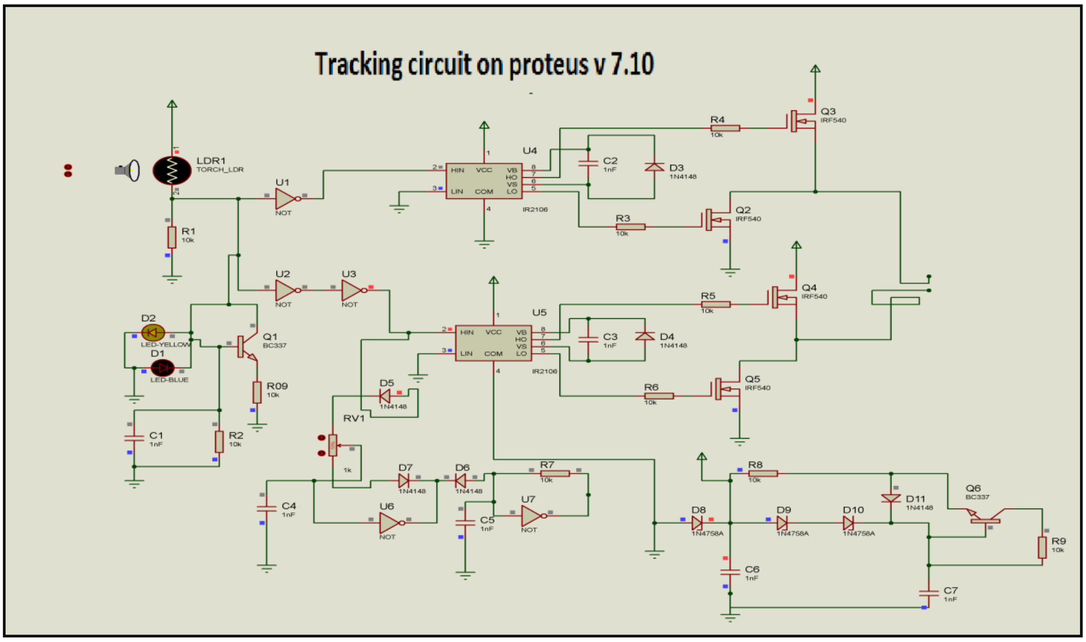


Fig. 4. 20 Tracking circuit build on proteus

To increase the tracking accuracy, a feedback loop derived from the disturbances in the process' model was introduced [7]. Main specification and function are discuss in result section and verified practically.

Summary

The experimental work was carried out at Kohinoor mill by taking the practical example of the industry and also checked for the prototype installed at Solar park of CES, NUST. All the work performed is explained step by step discussing every part of the parabolic trough. The difficulties in different steps and the alternative approach followed are also being explained. The most focus was given to the designing and appropriate tracking, whose results are being discussed later. By using different approaches it was tried to increase the efficiency of the system to great extent so that it will really contribute its part in the industry.

References

[1].Oo, L.L. and N.K. Hlaing, Microcontroller-Based Two-Axis Solar Tracking System. 2010: p. 436-440.

[2].Zarza, E., Medium Temperature Solar Concentrators (Parabolic-Troughs Collectors). Solar Energy Conversion and Photoenergy Systems, 2005. 1.

[3].Toliyat, H.A. and G.B. Kliman, Handbook of electric motors. Vol. 120. 2012: CRC press.

[4].Lee, C.-Y., et al., Sun tracking systems: A review. Sensors, 2009. 9(5): p. 3875-3890.

[5].Christopher, I.W., R. Ramesh, and C. Saravanan. Low cost automatic solar energy trapping system. in Electrical Energy Systems (ICEES), 2011 1st International Conference on. 2011. IEEE.

[6].Dicorato, M., et al. One-axis tracking optimization of Concentrating Solar Power plant for electricity production. in Universities Power Engineering Conference (UPEC), 2010 45th International. 2010. IEEE.

[7].Mousazadeh, H., et al., A review of principle and sun-tracking methods for maximizing solar systems output. Renewable and Sustainable Energy Reviews, 2009. 13(8): p. 1800-1818.

Chapter 5

RESULTS AND DISCUSSION

After the installation of the system the experimental work is performed in which the system is observed for some days under different conditions to get the best result according to the atmospheric condition of the region shown in figure 5.1.

Fig.5. 1 Parabolic trough collector

As, the system is installed in Islamabad so the monthly average air temperature for the whole year is been calculated for the Islamabad as given in figure 5.2 [1].

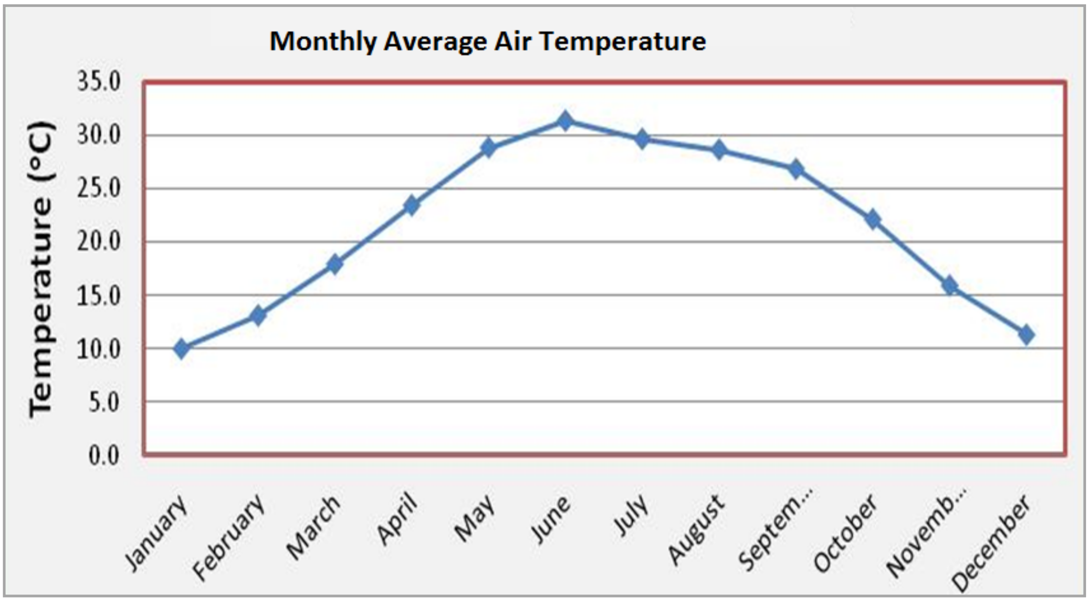


Fig.5. 2 Monthly average air temperature

Similarly the annual average daily solar radiation for the region is also calculated according to the date shown in figure 32.

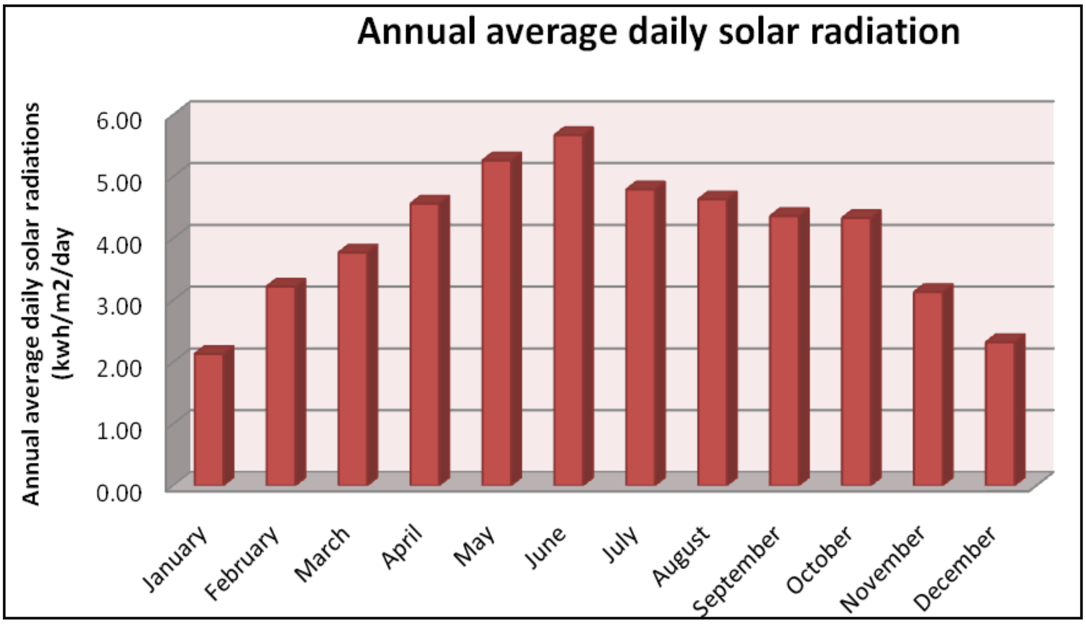


Fig.5.3 : Annual average daily solar radiation

5.1 Parabolic Calculator

Parabolic calculator was used to calculate and verify our exact dimension. Results of the parabolic calculator are as follow:

Table 5.1 :Different dimension of the parabolic collector

Linear diameter	81.32 inches
Diameter or width	65.00 inches
Depth or height	22.00 inches
Focal length	12.00 inches
Volume	36501.38 cubic inches
FLength/Diameter	00.18 inch
Length	144 inches
Weight	65kg

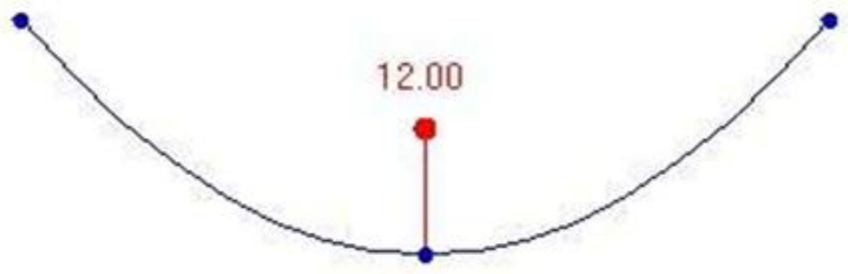


Fig.5. 4 The focus point determination using parabolic calculator

The focus point of the trough is shown in figure 5.4. The coordinates of the 18 segments of the trough are calculated where light rays fall and then reflected back to the receiver at focus [2].

Table 4.2 The coordinates of 18 segments where the light rays fall on the trough

X	Y
-32.50	22.00
-28.44	16.84
-24.38	12.38
-20.31	8.59
-16.25	5.50
-12.19	3.09
-8.13	1.38
-4.06	0.34
0.00	0.00
4.06	0.34
8.13	1.38
12.19	3.09
16.25	5.50

20.31	8.59
24.38	12.38
28.44	16.84
32.50	22.00

The Equation for a Parabola is:

$y = a(x^2) + b(x) + c$ ....(5.1)

The Coefficients a, b, c describing this Parabola are:

a: 2.08284023668639E-02, b: 0, c: -1.39081382833989E-15

Putting the value in (5.1)

$y = 2.08284023668639e^{-2}(x^2) + 0(x) - 1.39081382833989\ e^{-15}$ ....(5.2)

Equation (5.2) defines the parabolic equation of this system. The volume of a parabola is one half the area of the circular opening times the depth, written mathematically in equation (5.3).

$\text{Volume} = (\pi \times (\text{diameter}/2)^2 \times \text{height})/2$ ....(5.3)

Putting the value in (5.3)

The Volume for this parabola is:

Volume = $\pi \times (65 / 2)^2 \times 22) / 2$ = 36501.38 cubic inches.

5.2 Tracker Testing

Fig.5. 5 Tracker circuit while testing phase

The tracker is also being checked and the following results are deducted under the continuous usage for the following parameters:

- With respect to sunlight condition i.e. the response of tracker is checked in fused light ,full light, in ordinary bulb light and it is found satisfactory in all conditions.
- The auto scan option is also present in it and was tested in cloudy weather as the sun disappears it starts searching it.
- The special night shutdown mode is also present, which is observed that after sunset it reverts to its initial position and remain turned off till sunrise.
- The motor response with respect to tracker is also satisfactory based on the signal given by the tracker; the motor will abruptly move the trough to the desired position [3].

5.3 Strength Test

In order to check the strength of the system that it can withstand in extreme weather and other condition. The trough is hanging onto the stands and checked in three different ways:

5.3.1 Free moving test:

We observe it in different wind pressure and were a bit lucky that there was a strong breeze on the days of our testing specially on 31 may when the wind pressure was almost 100 kmph .Which make the dish of weight of 65 kg swings freely again and again as shown in figure 5.6. But our system survives and stands remain stiff on its position and not even single breakage or crack was there to any part of system.

Fig.5. 6 The trough freely moving in extreme weather

5.3.2 Pulley with belt (without motor)

After sometime we have tied the dish to pulley with the belt to check that how much it will resist this extreme pressure and can remain at its fixed position. As we observe that the dish will remain almost at the same position where it is fixed only moves a fraction of degrees.

5.3.3 Pulley with the external support of motor

In this case we have also connected the gear and motor to the pulley which provide it an external force against the pressure of air. When its left in these extreme condition, it provides us a great advantage to check the system as a whole in the running position. Here we observe the how strong and elastic our belt is, how much torque or force will motor require in such condition and the support by the gear mechanism.

But this test was really successful that the motor and gear mechanism kept our system align at its fixed position as commanded by the tracker. Which make us really satisfied about our system strength.

5.4 AUTOCAD model

In order to visualize the real picture of our design using the actual dimension calculated above. The 3-D model on AUTOCAD is generated [4]. The result and design appeals in figure 5.7.

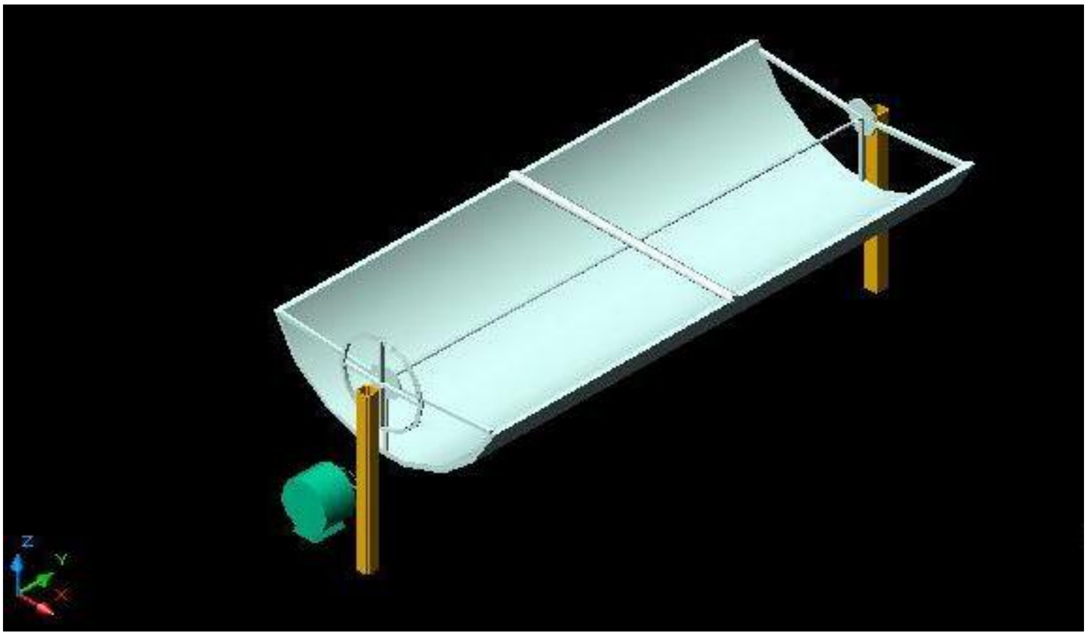


Fig.5. 7 The actual drawing of parabolic trough collector made on AUTOCAD

The experiment starts from 9am in the morning and observed till 5 pm in the evening. Table 6 represents the different parameters of trough while calculated in working position of trough on a bright sunny day.

On the day of testing the condition were:

Atmospheric temperature of that day = 40 ˚C with a clear sunny day

Temperature of outer side of cu tube =135˚C

Temperatures at different points on pipe= 90˚C, 95˚C, 135˚C, 110˚C, 98˚C

Average inlet temperature of water =34˚C

Average outlet temperature of water=86˚C

Table 5.3 Showing the different temperature in clear sunny day of tracking system

Time	Inlet temperature	Outlet temperature	Receiver Surface temperature	Efficiency
9.00	28˚C	35˚C	50˚C	20%
10.00	30˚C	60˚C	80˚C	50%
11.00	30˚C	75˚C	95˚C	60%
12.00	32˚C	85˚C	115˚C	62%
13.00	34˚C	98˚C	145˚C	65%
14.00	34˚C	88˚C	135˚C	61%
15.00	34˚C	85˚C	110˚C	59.5%
16.00	32˚C	83˚C	105˚C	60%
17.00	32˚C	75˚C	98˚C	57.3%

In order to get the best results we have observed the system in two different days having different weather conditions. On the bright sunny day and when the sun is partially covered with clouds during day. We compare outlet temperature of water passing through the receiver pipe in both cases while tracking. The maximum temp attained of water passing through receiver was 98˚C on the bright sunny day. As shown in figure 5.8.

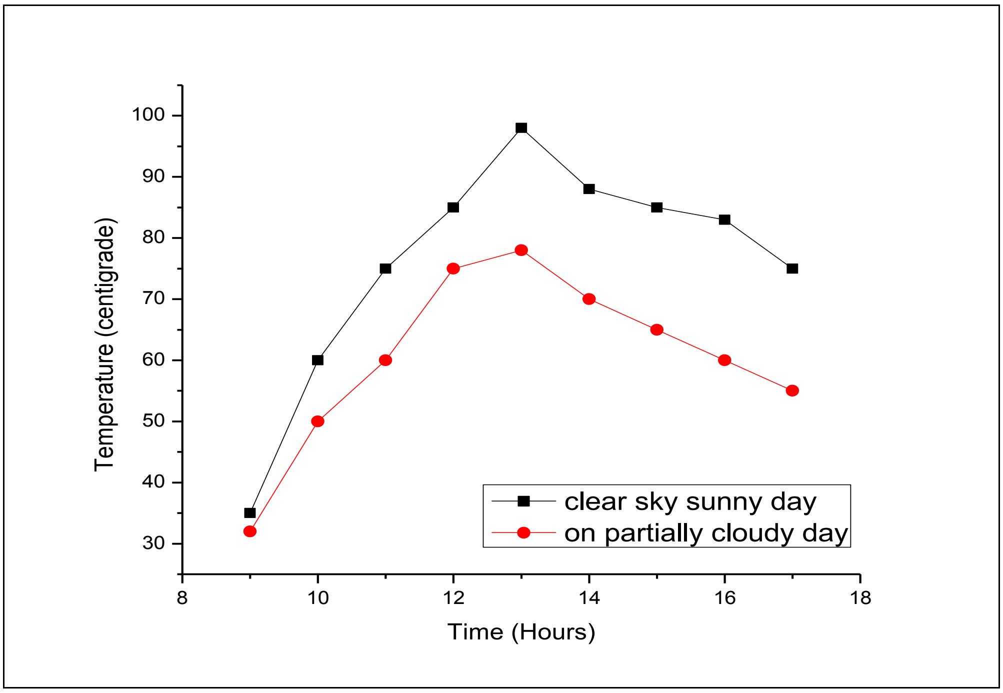


Fig.5. 8 Graph between water temperature on partially cloudy and bright sunny day with tracking

The comparison of the solar trough data in fixed condition at the position of peak time of sun with the one when subjected to tracking .Both cases are checked on the alternative days having almost same weather condition [5].

Table 5.4 The different temperature and efficiencies for tracking and fixed system

Time	Temperature inlet	Temperature on with fixed system	Efficiency of fixed system	Temperature with tracking system	Efficiency of tracking system
9.00	28˚C	32˚C	6.25%	35˚C	20%
10.00	30˚C	40˚C	22.5%	60˚C	50%
11.00	30˚C	50˚C	36%	75˚C	60%
12.00	32˚C	75˚C	57.3%	85˚C	62%
13.00	34˚C	82˚C	58.5%	98˚C	65%
14.00	34˚C	48˚C	33.3%	88˚C	61%
15.00	34˚C	44˚C	31.8%	85˚C	59.5%
16.00	32˚C	42˚C	28.5%	83˚C	60%
17.00	32˚C	40˚C	25%	75˚C	57.3%

The temperature in both cases was maximum at 13:00 hours. And the temperature of water passing through receiver at outlet was 98˚C in tracking and 82˚C in the fixed (as angle was fixed at peak time).

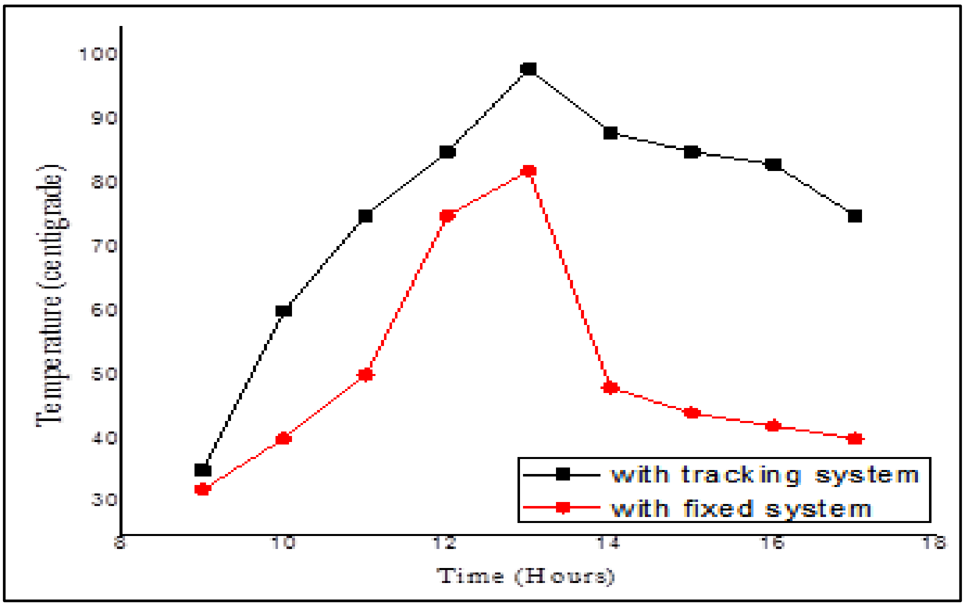


Fig.5. 9 Graph between water temperatures of tracking and fixed system

The thermal efficiency is evaluated using the following sets of Equations.

$\text{Input(W)} = \text{input radiation} \times \text{area}$..(5.4)

$\text{Output(Q)} = m \times Cp \times (T_{in} - T_{out})$..(5.5)

$\text{Thermal efficiency(ή)} = \text{Output(Q)/Input(W)}$ ....(5.6)

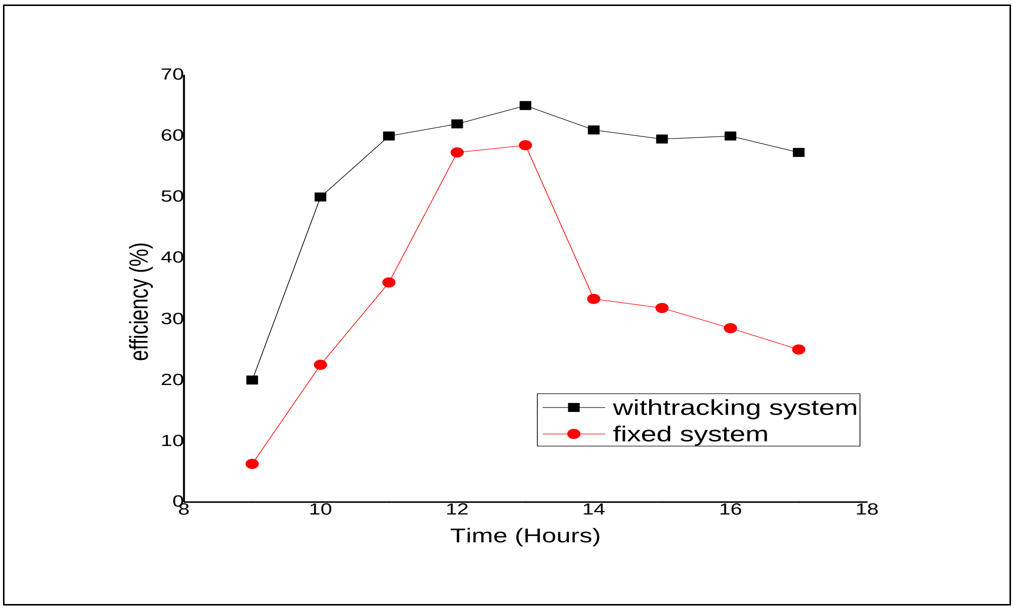


Fig.5. 10 Graph between efficiencies of fixed and tracking system

The temperature of the fixed system varies at different time of the day and was maximum only at peak time when the slope of the trough becomes zero with the sun rays. Whereas the tracking system once it gets into the sun path it seen that the rays trap throughout the day and attains very good temperatures all the day in figure 5.9. Similarly the efficiency of the system which are calculated in both cases, but the fixed system after reaching at its peak value decrease abruptly, whereas the efficiency of tracking system remains almost the same varying between 60 to 65% as shown in figure 5.10.

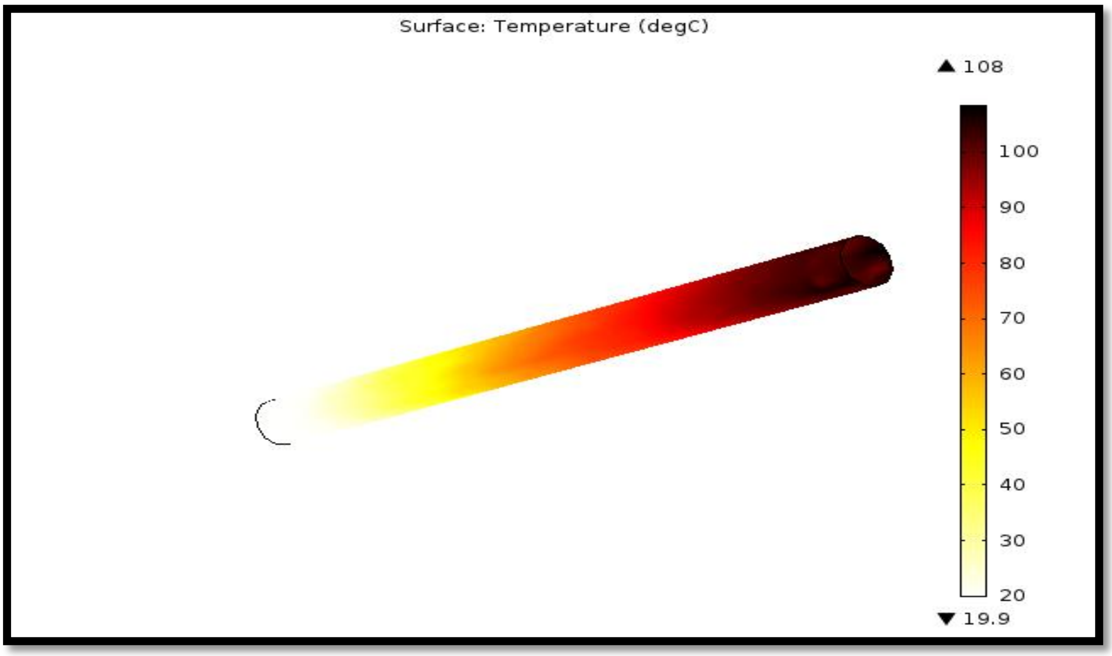


Fig.5. 11 Temperature at different level while passing through heat exchanger

On the basis of experimental data for the increasing temperature in concentrator, heat exchanger model was designed and simulated using COMSOL [6]. By this we will be able to get the results for the temperature of the hot water at different points as shown in figure 5.11.

5.5 Cost Analysis

By gathering the real data from the industry and using the performing the calculation the cost analysis of the project is also performed. Total overall water consumption by the plant every day is 44500 gallon of water. This is provided by the 11 tube wells operating at the same time. The 280 ton or 899 BTU steam is required for different process like dying , processing and printing on daily basis. The main source of steam and hot water is wood and gas. In summer the natural gas is best option but for winter wood is used because of shortage of natural gas.

Table 5.5 The comparison between using natural gas and wood

Source	Wood	Natural gas
average amount used per day	240 ton or 217724 kg 1ton =907.185kg	16373m^3 or 577.98 MMBTU 1m^3 = 0.0353MMBTU
Unit price	Rs. 9.4/kg	Rs.638.32/MMBTU
Total Daily cost	217724 kg* 9.4 = Rs. 20,46605	577.98MMBTU*6.38.32 = Rs. 3,68936.19
Operating efficiency	45%	88%

The hot water from the PTC is directly feed to the boiler the average efficiency of the PTC system is 65%. So the hot water provided by the 50 PTC systems per day at the flow rate of 6L/min having the sunshine of 8 hours is 2880 liter or 760 gallon. It is expected that parabolic trough collector will be able to compensate 5 % of the present cost [7].

Daily saving by the PTC if mix with Natural gas (solar thermal hybrid system) =
Rs. 18,446.5.

Daily saving by the PTC if mix with wood (solar thermal hybrid system) =
Rs. 102330.25

Total cost of trough install at one site = 4.5 million.

In case of gas the recovery of capital cost is expected to be in 242 days or 8 months based in daily saving.

In case of wood the recovery of capital cost is expected to be in 44 days or 1.5 month based on daily saving.

Whereas, the average life of solar project is 10-15 year. So it's really expected to be a great project and PTC has great future in countries like Pakistan.

Summary

The result of the project are quite impressive and up to our expectations. The most focus was given to the designing and appropriate tracking. The system is checked in different weather condition and its response was being observed. The system after making the structure was advanced by introducing single axis tracking and its results were being compared with the initial fixed one. The average efficiency is almost double by introducing tracking mechanism. The most impressive was cost analysis which was based on the actual consumption of gas and wood used in a specific industry and the compensation in its cost which the PTC ensures by its integration with them.

References

[1].Engr. Shahrukh Saleem, P.D.A.u.A., Analysis & Design of Parabolic Trough Solar Thermal Power Plant for Typical Sites of Pakistan. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), May – Jun. 2014. 9(3).

[2].Kearney, D.W. Parabolic trough collector overview. in Presentation at the Parabolic Trough Workshop 2007at NREL, Golden, CO. 2007.

[3].Lee, C.-Y., et al., Sun tracking systems: A review. Sensors, 2009. 9(5): p. 3875-3890.

[4].Pradeep Kumar K V, S.T., Venkatesh Reddy, Design, Fabrication and Experimental Testing of Solar Parabolic Trough Collectors with Automated Tracking Mechanism.INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING, 2013.

[5].Dicorato, M., et al. One-axis tracking optimization of Concentrating Solar Power plant for electricity production. in Universities Power Engineering Conference (UPEC), 2010 45th International. 2010. IEEE.

[6].Saleem, U., M.A. Hanif, and A. Waqas, Alternate method for steam generation and hot water in Textile and Leather Industry using Solar Thermal Technology. 2014.

[7].Christopher, I.W., R. Ramesh, and C. Saravanan. Low cost automatic solar energy trapping system. in Electrical Energy Systems (ICEES), 2011 1st International Conference on. 2011. IEEE.

Conclusion and Recommendations

Conclusion

Energy demand and the concomitant depletion in foregoing conventional resources will increase with great pace in next decade. To meet the energy demand developing countries must move to renewable. Parabolic trough collector was design, fabricated and successfully operated with effective efficiency of 40% with static system and efficiency of 62% with tracking. By introducing tracker in the system its efficiency is greatly improve. Design tracking system bears good potential for replication in other industries nationwide and provides cost effective method for hot water application. Pilot project installed at Kohinoor mills act as a demonstrable project for other industries of the region, that its really reliable and useful renewable gadget. The outlet temperature of water up to 98˚C is being achieved. This investigation will help devise science and technology based energy policy. Cost analysis will provide the better justification to understand the benefits of the project in term of saving. Being renewable effective utilization of solar energy will reduce pollution and motivate people to move towards the alternate energy resources.

Recommendations

The system is best in all term as a pilot project but can be more beneficial if some changes will be done like.

- The actuator should be introducing replacing the motor and gear system to make it more efficient.
- The copper pipe should be replaced by the vacuum tube to limit the losses caused by the external environment.
- The gas valves should be added to decrease the high pressure inside the pipe which can cause them burst.
- The system should be advance to dual axis tracking to get the more use of sunlight.
- To decrease the cost, one array of the troughs should be control by the single tracker and motor of high power rating

Annexure I

Design and analysis of single axis sun tracking parabolic trough collector for industrial water heating

Husnain Bhatti, Shahmir Ahmed, Waqar Ahmed, Dr. Muhammad Bilal khan, Irfan Khan Niazi

Abstract:

Pakistan is facing a huge shortage of natural gas and electric power. Meeting the domestic requirements of gas and electricity is becoming difficult, so it's the time to move on Renewable rather than relying on the conventional resources. The use of solar is a promising option. Pakistan geographically lies on Sun Belt having maximum solar radiance and sun shine of 6 - 8 hours a day. The main theme of the paper is design, development, testing and evaluation of single-axis solar tracking. Parabolic trough collector (PTC) act as prototype for instructional and demonstration purposes. The proper dimension of the PTC was calculated using parabolic calculator and constructed on AUTOCAD. The PTC was examined under different weather conditions. COMSOL was used to simulate heat exchanger and the maximum temperature of 98˚C was obtained. The average efficiency of the tracking PTC was 50% more than the identical fixed collector design.

Key words. Parabolic trough collector (PTC), AUTOCAD, Tracking, COMSOL

1. Introduction:

Energy crisis in Pakistan is one of the serious challenges the country is facing today. Electricity, gas, water and fuel are necessary part of our daily life and its outage has badly influenced our economy and living. Increase in industrial activity and failure to provide enough energy from the conventional resources has really harmed the country. The resources of fossil fuel which are available are becoming so expensive and depleting. Traditionally, industries are using gas or electric power for generating hot water and steam.

The industry is spending huge heavily for gas, furnace oil and electricity. As the country is already facing shortage of gas and electric power, meeting the domestic requirements of gas and electricity is becoming difficult .This is an important question for industrial sector that how long more will they depend on conventional resources.

The hot water and steam is used in various processes and production stages in Pakistan. The major user of hot water and steam include

- Textiles spinning and processing Industry
- Leather processing industry
- Food processing industry
- Sugar industry
- Chemical industry

So it's the right time to move on Renewable rather than relying on the conventional resources which are depleting rapidly. Most of Pakistan lies in sunny belt of the earth, with the sun shine of 6 – 8.5 hours daily having the greatest amount of radiant energy more than 90% of solar radiation, which comes as direct radiation because of the limited cloud coverage and clear sunny weather [1].

Different concentrating technologies have been developed or are currently under development for various applications in solar throughout the world. The Parabolic Trough Solar Collectors system will undoubtedly provide a significant contribution to efficient, economical, sustainable renewable and clean energy supply to developing countries with positive effect on environmental activities within next decade [2]. Figure.1 shows the annual DNI Map of Pakistan.

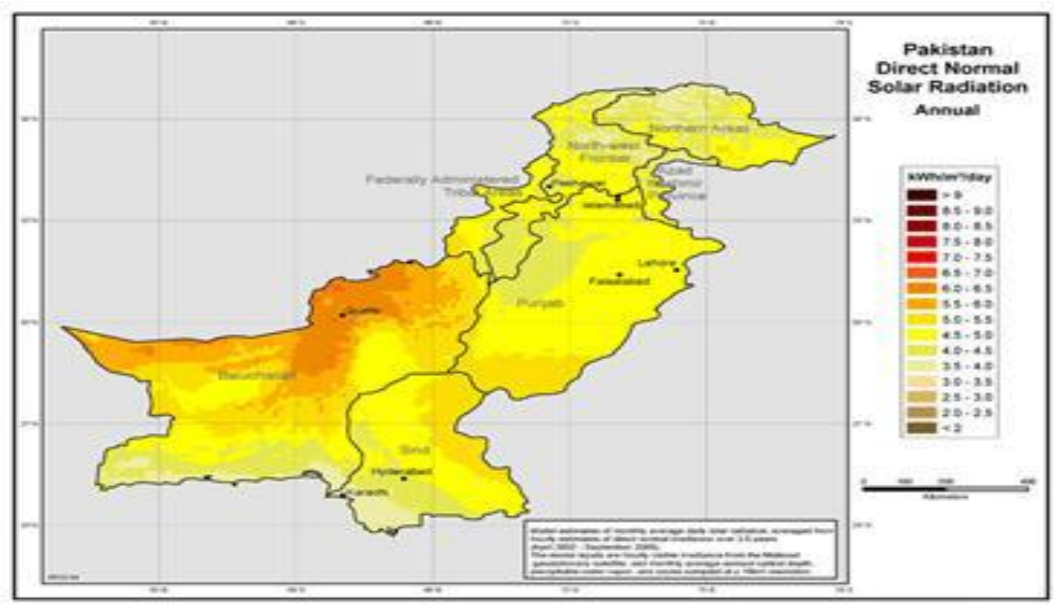


Figure 1. Pakistan direct normal solar radiation

Much work is being done on this technology throughout the world and especially in Pakistan. Saleem et al investigate the feasibility of a Parabolic Trough Solar Thermal Power Plant (PTSTPP) for typical sites of Pakistan. The solar resource of the country is assessed against the required insolation levels. An optimum potential site with suitable irradiance level is identified and evaluated [3]. Iqbal et al have worked on mechanical design of parabolic trough and experimental testing for its use in generating electricity using steam engine [4]. The numerical investigation of parabolic trough collector was performed by Cheng et al and Reddy et al[5, 6].Han at el had enhances the performance of parabolic trough collector by integrating tower collector which give a new way for utilizing solar energy more efficiently and economically [7]. Roberto Grena made a simulation that evaluates the optical efficiency and builds the distribution of the energy absorbed on the receiver surface [8].Raja et al give an overview on the cost, performance and risk of parabolic trough technology and suggested that it can be fairly well established by the experience of the existing operating parabolic trough plant . They proposed that by tracking the sun from sunrise to sunset, the thermal efficiency of a parabolic trough solar collector can greatly improved [1]. Odeh et al present the design, development, testing and evaluation of an educational single-axis solar tracking parabolic trough collector that represents a standalone system to produce process heat at a moderate temperature for instructional and demonstrative purposes. By introducing tracking the efficiency of system reached up to 60% at noon [9].

2. Designing of Parabolic Trough Collector:

A prototype of single axis parabolic trough collector is designed to get hot water at ambient condition. The system mainly consists of 4 parts; parabolic trough reflector, a receiving tube, motors and gear mechanism and the tracking system.

2.1 Parabolic trough reflector

A highly polished stainless steel sheet of grade 304(26SwG) is used as a reflecting surface. It has the reflectance of about 0.80. Depending on the reflecting area a very high temperature can be attained. The sheet is fixed on the frame made by the 7 length of stainless steel pipe of 5mm arranged in parabolic shape having the rim angle of 74˚. These components are meant to focus beam of radiation to the receiver. Therefore, the focus of the trough should be correct as shown in figure 2. The parabolic curve is able to focus all the rays at focal point which in 3-D called as focal line, clearly seen in figure 3. The focus of the trough can be calculated by (1).

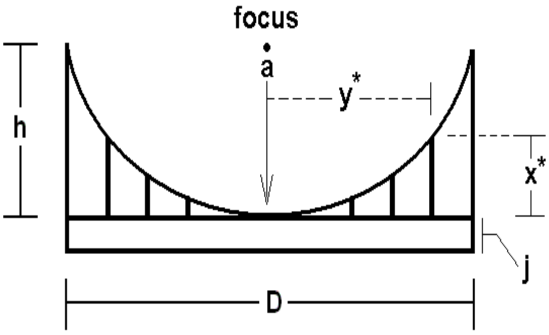


Figure 2.focus and other parameters

......Figure 3. The trough at its full focus

$y^2 = 4ax$ (1)

As , y = D/2 , h=x

$a = D^2/16h = 12$ inches. (2)

Parabolic calculator was used to calculate and verify our exact dimension:

Table 1.Different dimension of the parabolic collector

Linear diameter	81.32 inches
Diameter or width	65.00 inches
Depth or height	22.00 inches
Focal length	12.00 inches

Volume	36501.38 cubic inches
FLength/Diameter	00.18 inch
Length	144 inches
Weight	65kg

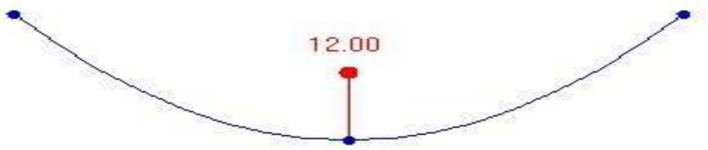


Figure 4. The focus point determination using parabolic calculator

The focus calculated in equation (2) co-focuses with the one shown in figure 4. The coordinates of the 18 segments of the trough are calculated where light rays fall and then reflected back to the receiver at focus.

Table 2. The coordinates of 18 segments where the light rays fall on the trough

X	Y
-32.50	22.00
-28.44	16.84
-24.38	12.38
-20.31	8.59
-16.25	5.50
-12.19	3.09
-8.13	1.38
-4.06	0.34

0.00	0.00
4.06	0.34
8.13	1.38
12.19	3.09
16.25	5.50
20.31	8.59
24.38	12.38
28.44	16.84
32.50	22.00

The equation for a Parabola is:

$$y = a(x^2) + b(x) + c \quad (3)$$

The Coefficients a, b, c describing this Parabola are:

a: 2.08284023668639E-02, b: 0, c: -1.39081382833989E-15

$$y = 2.08284023668639e^{-2}(x^2) + 0(x) - 1.39081382833989\ e^{-15} \quad (4)$$

equation (4) defines the parabolic equation of this system. The volume of a parabola is one half the area of the circular opening times the depth, written mathematically in equation (5).

$$\text{Volume} = (\pi \times (\text{diameter}/2)^2 \times \text{height})/2 \quad (5)$$

The Volume for this parabola is:

Volume = $\pi \times (65 / 2)^2 \times 22) / 2$ = 36501.38 cubic inches.

A laser pointer can be used for checking the real shape accuracy of any reflector. Some troughs aren't parabolic. So by orthogonal (perpendicular) mounting of the laser pointer to point directly into the trough and translating the laser along a rigid support, one can simulate parallel rays entering the dish. These can be reflected off the back of the dish and the focus movement may be observed [10].

The concentration ratio of PTC is the ratio between collector aperture area and the total area of the absorber tube shown in equation (6). Its value mostly lies between 20 and 70. It actually represents the reflector quality. A higher concentration ratio allows the collector to reach higher temperature with minimum losses [11].

$C = I^{\circ}/\pi \times D^{\circ}$, C= 20.38. (6)

I˚= parabola width. D˚=outer diameter of absorber pipe

In order to visualize the real picture of our design. The 3-D model on AUTOCAD is generated. The result and design appeals in figure 5.

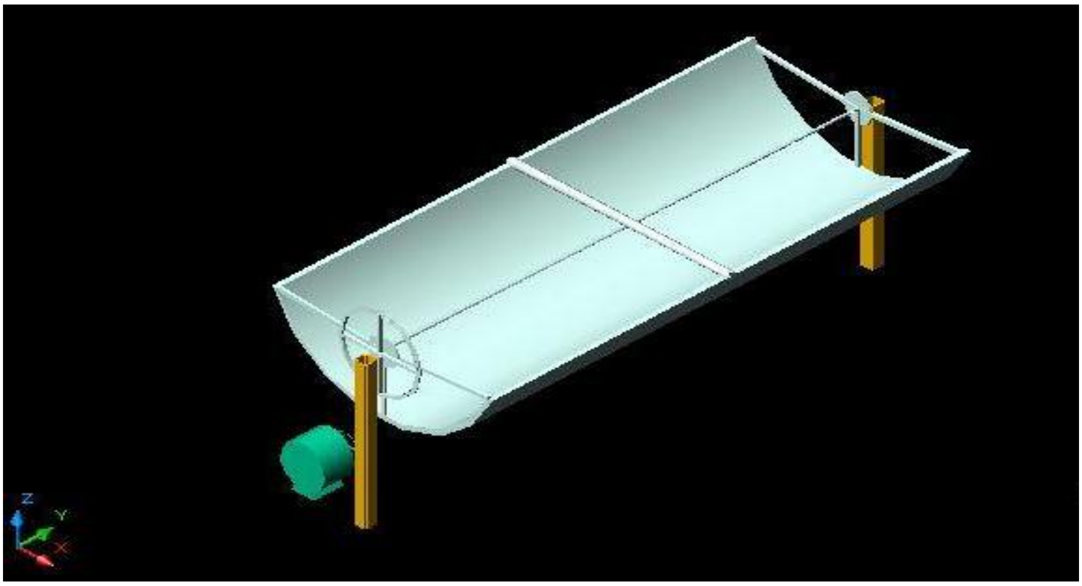


Figure 5.AUTOCAD 3-D model of trough

The stand of the trough should be kept very strong. It should be able bear the weight of the dish in extreme conditions. The trough is supported on the two pillar of steel having a specific height and is fix on the concrete surface with the help of catchers to make the pillar stiff.

2.2 Receiver Tube

Figure 6: The copper tube used as a receiver

It is one of the most important parts of the system. The width of the receiver is estimated from the width of solar flux pattern in focal line. In our case we are using Cu tube of 1 inch diameter and 12.5 feet long passing from the centre of the trough from the focus line, well supported by the ball bearings and Teflon rings shown in figure 6. The accompanied by heat transfer is the different type of losses shown in equation (7)

Losses=convection + radiation + conduction (through brackets holding tube) (7)

The primary loss is convection which is due to the external environment effect different parameters e.g wind speed cooling tube, outer temperature, humidity etc [12].

2.3 Motors and Gear Mechanism

Figure 7. The motor and gear mechanism of the system

The motor and gear mechanism helps the trough to align with the sun for maximum time as guided by the tracker. They are connected with the trough by the pulleys and belts. The motor will move the trough to certain degree as commanded by the tracker .The12V DC motor has been used which has sufficient torque to move the trough weighing 65 kg. The drive motor specification is shown in table 3:

Table 3. Electrical specification of motor

Nominal voltage	Nominal power	No load current	Stall current	No load speed(rpm)	Stall torque
12V	150W	2.5-4.5A	65A	15-40	95Nm

The motor is connected with the gear assembly which converts the electrical power to the mechanical torque. The gear train has the gear ratio of 1:3. As, the rated torque of the motor is above 35 rpm but the required speed is quite less than that, so the gear mechanism is really helpful, to move the trough up to 0.25˚ after every 30 sec. These motor and gear mechanism not only increase the efficiency of the system but also protect the trough in extreme condition e.g. from high wind pressure and misalignment under different condition etc.

2.4 Tracker

A simple and accurate single axis electronic solar tracker is being used for the tracking purpose whose circuit diagram is shown in figure 8.It has pair of green LED's which work as photovoltaic sensors.

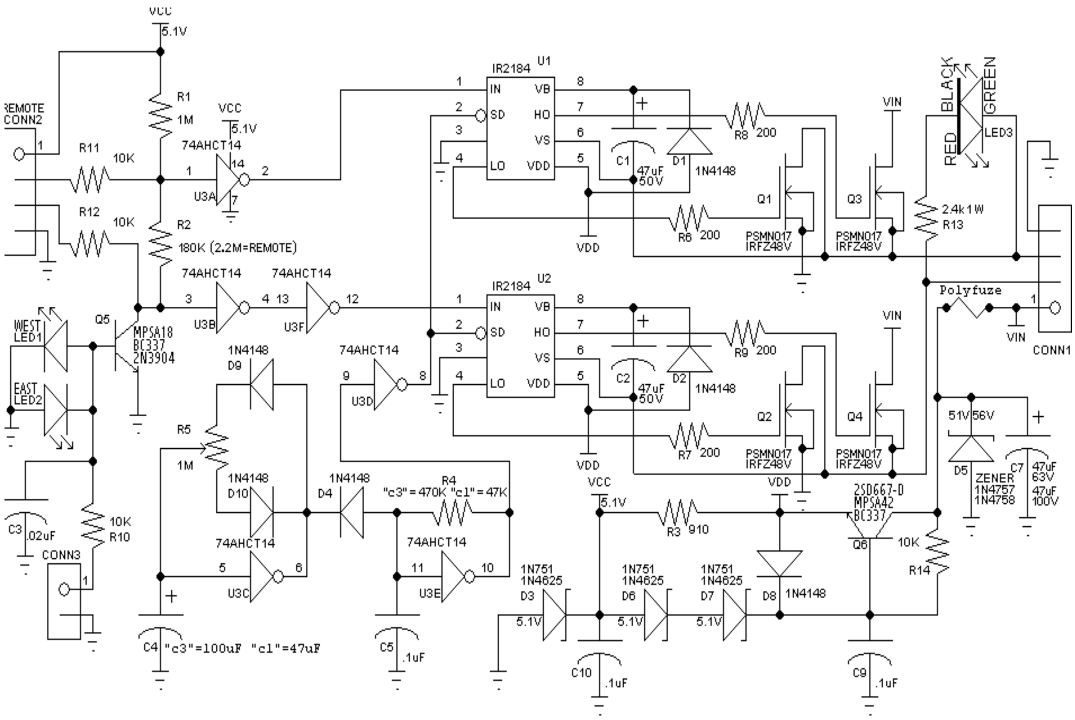


Figure 8. The circuit diagram of the tracker

The variable resistor is serves to adjust the duty cycle from 0% to 100%, cycle time in this case is set at 30 sec. To protect from over current, a fuse is used in the circuit . Similarly for the over temperature condition the MOSFET is thermally coupled with fuse to the transistor. The board has also enough spacing to reduce the tendency of short circuit .The wide operating voltage range from 10.5V to 44V. The tracker is also being checked under the continuous usage for the following parameters:

- With respect to sunlight condition e.g. in fused light, full light, in ordinary bulb light response and it is found satisfactory in all conditions.
- The auto scan option is also present in it and was tested in cloudy weather as the sun disappears it starts searching it.
- The special night shutdown mode is also present, which is observed that after sunset it reverts to its initial position and remain turned off till sunrise.

➢ The motor response with respect to tracker is also satisfactory based on the signal given by the tracker; the motor will abruptly move the trough to the desired position.

➢ The output of the system is greatly improved by the help of the tracker. Hence, increases the efficiency to a great extent.

3. Experimentation and Result

After the installation of the system the experimental work is performed in which the system is observed for some days under different conditions to get the best result according to the atmospheric condition of the region shown in figure 9. The experiment starts from 9am in the morning and observed till 5 pm in the evening.

Figure 9. Parabolic trough collector

As, the system is installed in Islamabad so the monthly average air temperature for the whole year is been calculated for the Islamabad as given in figure 10.

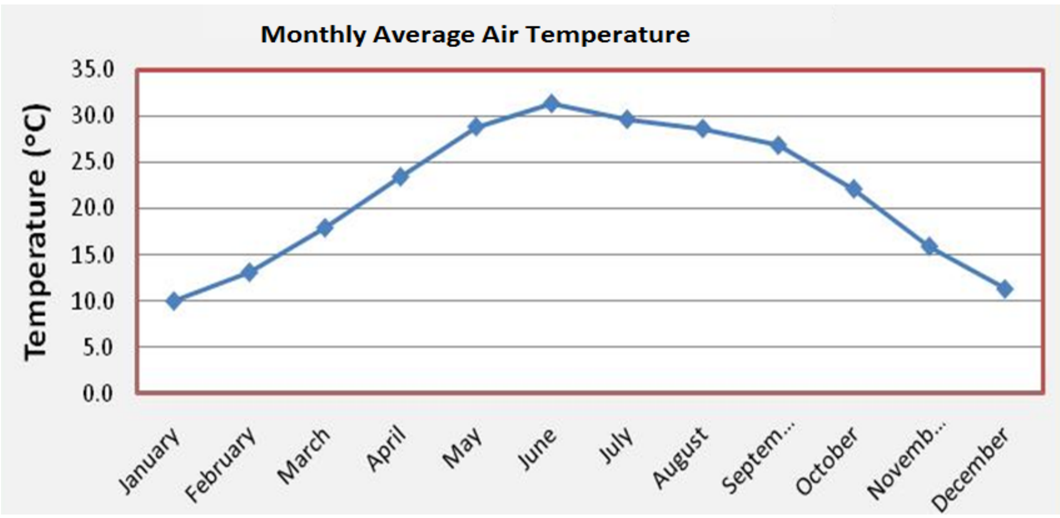


Figure 10.Monthly average air temperature

Similarly the annual average daily solar radiation for the region is also calculated according to the date shown in figure 11.

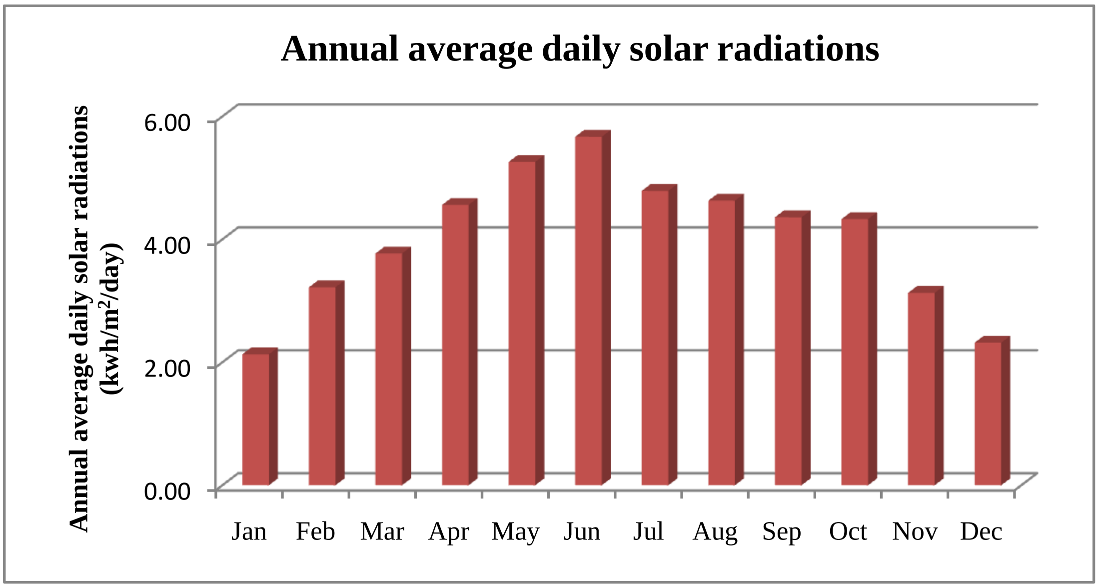


Figure 11.Annual average daily solar radiation

Table 4 represents the different parameters of trough while calculated in working position of trough on a bright sunny day.

Table 4.Showing the different temperature in clear sunny day of tracking system

Time	Inlet temperature	Outlet temperature	Receiver Surface temperature	Efficiency
9.00	28˚C	35˚C	50˚C	20%
10.00	30˚C	60˚C	80˚C	50%
11.00	30˚C	75˚C	95˚C	60%
12.00	32˚C	85˚C	115˚C	62%
13.00	34˚C	98˚C	145˚C	65%
14.00	34˚C	88˚C	135˚C	61%
15.00	34˚C	85˚C	110˚C	59.5%
16.00	32˚C	83˚C	105˚C	60%
17.00	32˚C	75˚C	98˚C	57.3%

In order to get the best results we have observed the system in two different days having different weather conditions. On the bright sunny day and when the sun is partially covered with clouds during the day. We compare the outlet temperature of water passing through the receiver pipe in both cases while tracking. The maximum temperature attained of water passing through receiver was 98˚C on the bright sunny day. As shown in figure 12.

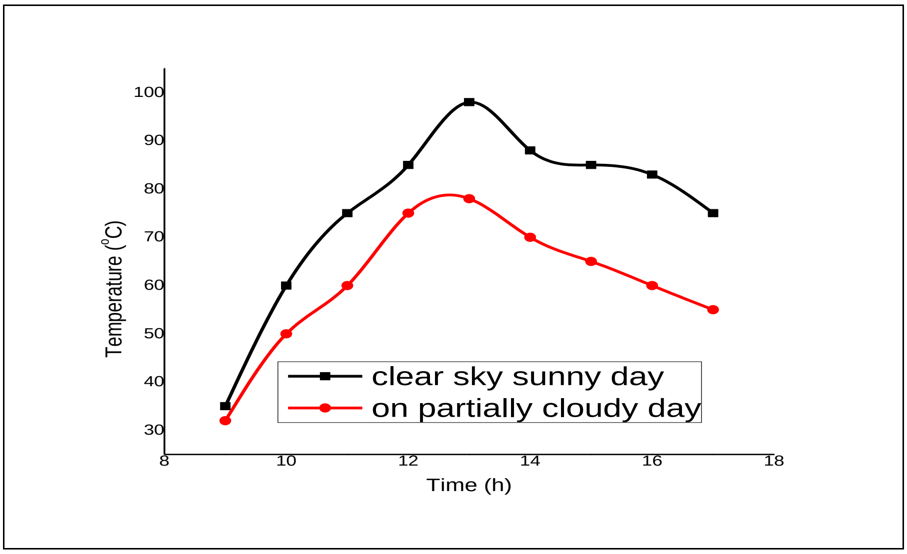


Figure 12. Graph between water temperature on partially cloudy and bright sunny day with tracking

We compared the solar trough data in fixed condition at the position of peak time of sun with the one when subjected to tracking .Both cases are checked on the alternative days having almost same weather condition.

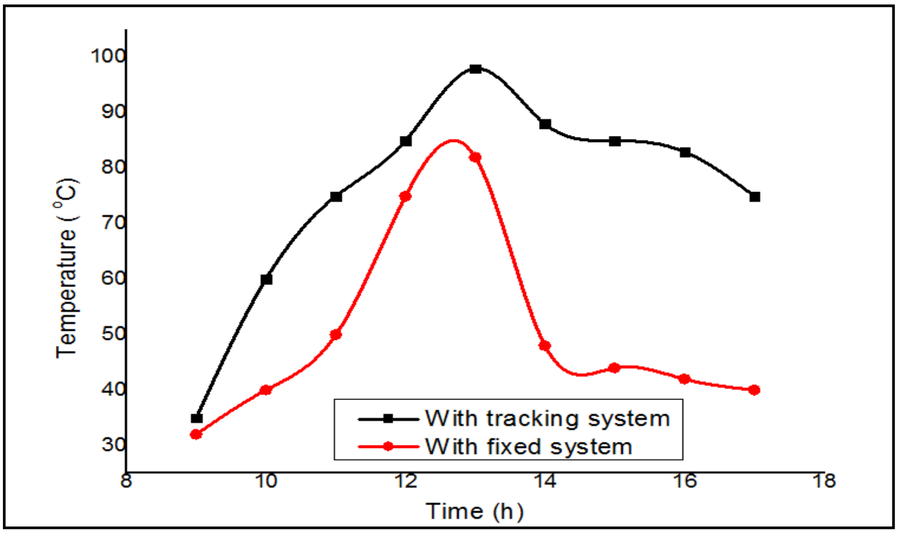


Figure 13. Graph between water temperatures of tracking and fixed system.

The temperature in both cases was maximum at 13:00 hours. And the temperature of water passing through receiver at outlet was 98˚C in tracking and 82˚C in the fixed (as angle was fixed at peak time). The thermal efficiency is evaluated using the following sets of equations.

$$\text{Input(W)} = \text{input radiation} \times \text{area} \quad (8)$$

$$\text{Output(Q)} = m \times Cp \times (T_{in} - T_{out}) \quad (9)$$

$$\text{Thermal efficiency}(\acute{\eta}) = \text{Output(Q)}/\text{Input(W)} \quad (10)$$

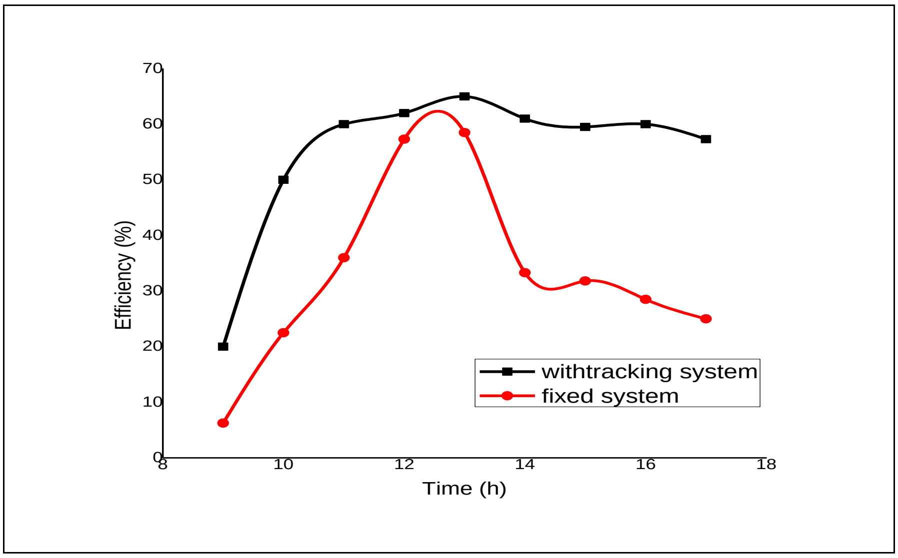


Figure 14. Graph between efficiencies of fixed and tracking system

The temperature of the fixed system varies at different time of the day and was maximum only at peak time when the slope of the trough becomes zero with the sun rays. Whereas the tracking system once it gets into the sun path it seen that the rays trap throughout the day and attains very good temperatures all the day in figure 13. Similarly the efficiency of the system which are calculated in both cases, but the fixed system after reaching at its peak value decrease abruptly, whereas the efficiency of tracking system remains almost the same varying between 60 to 65% as shown in figure 14.

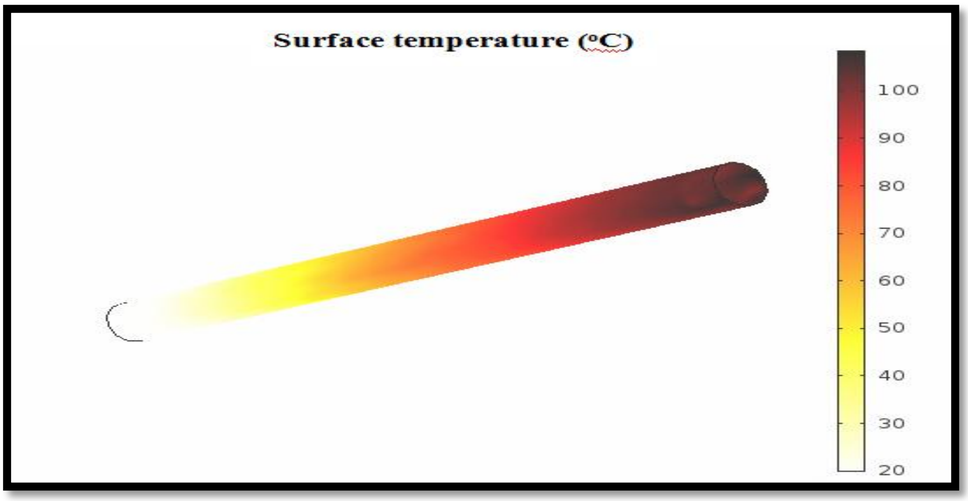


Figure 15: Water temperature at different level while passing through heat exchanger

On the basis of experimental data for the increasing temperature in concentrator, heat exchanger model was designed and simulated using COMSOL. By this we will be able to get the results for the temperature of the hot water at different points as shown in figure 15.

4. Conclusion

The energy demand and the concomitant depletion in foregoing conventional resources will increase with great pace in the coming years. To meet the energy demand developing countries must move to renewable. In this paper a prototype of parabolic trough collector is utilized which can act as a demonstrable project for the industries of the region, that it’s really reliable and useful renewable gadget. By making large reflector the industry can get the hot water and steam through this form of energy. The designed system fortify 25 to30% of more energy conversion than the static system. The outlet temperature of water up to 98˚C is being achieved. By introducing tracker in the system its efficiency is greatly improved.

References:

[1] Raja, N.K., et al., Design and Manufacturing of Parabolic Trough Solar Collector System for a Developing Country Pakistan. Journal of American Science, 2011. 7(1).

[2].Kearney, D.W. Parabolic trough collector overview. in Presentation at the Parabolic Trough Workshop 2007at NREL, Golden, CO. 2007.

[3].Engr. Shahrukh Saleem, P.D.A.u.A., Analysis & Design of Parabolic Trough Solar Thermal Power Plant for Typical Sites of Pakistan. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), May – Jun. 2014. 9(3).

[4].Iqbal, S., et al. Design, fabrication and analysis of solar parabolic trough collector for steam engine. in Robotics and Emerging Allied Technologies in Engineering (iCREATE), 2014 International Conference on. 2014. IEEE.

[5].Cheng, Z., et al., Three-dimensional numerical study of heat transfer characteristics in the receiver tube of parabolic trough solar collector. International Communications in Heat and Mass Transfer, 2010. 37(7): p. 782-787.

[6].Reddy, K., K.R. Kumar, and G. Satyanarayana, Numerical investigation of energy-efficient receiver for solar parabolic trough concentrator. Heat Transfer Engineering, 2008. 29(11): p. 961-972.

[7].Han, W., et al., Performance Enhancement of a Solar Trough Power Plant by Integrating Tower Collectors. Energy Procedia, 2014. 49: p. 1391-1399.

[8].Grena, R., Optical simulation of a parabolic solar trough collector. International Journal of Sustainable Energy, 2010. 29(1): p. 19-36.

[9].Odeh, S.D. and H.I. Abu-Mulaweh, Design and development of an educational solar tracking parabolic trough collector system. Global Journal of Engineering Education, 2013. 15(1).

[10].Oo, L.L. and N.K. Hlaing, Microcontroller-Based Two-Axis Solar Tracking System. 2010: p. 436-440.

[11].Zarza, E., Medium Temperature Solar Concentrators (Parabolic-Troughs Collectors). Solar Energy Conversion and Photoenergy Systems, 2005. 1.

Appendix

74AHC14; 74AHCT14

Hex inverting Schmitt trigger

Rev. 05 — 4 May 2009 **Product data sheet**

1. General description

The 74AHC14; 74AHCT14 is a high-speed Si-gate CMOS device and is pin compatible with Low-power Schottky TTL (LSTTL). It is specified in compliance with JEDEC standard No. 7A.

The 74AHC14; 74AHCT14 provides six inverting buffers with Schmitt-trigger action. They are capable of transforming slowly changing input signals into sharply defined, jitter-free output signals.

2. Features

- Balanced propagation delays
- All inputs have Schmitt-trigger actions
- Inputs accept voltages higher than V_{CC}
- Input levels:
  - For 74AHC14: CMOS level
  - For 74AHCT14: TTL level
- ESD protection:
  - HBM EIA/JESD22-A114E exceeds 2000 V
  - MM EIA/JESD22-A115-A exceeds 200 V
  - CDM EIA/JESD22-C101C exceeds 1000 V
- Multiple package options
- Specified from −40 °C to +85 °C and from −40 °C to +125 °C

Functional diagram

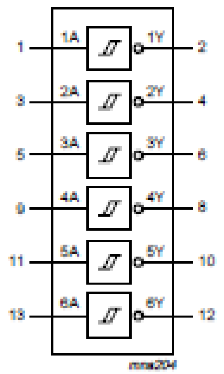


Fig 1. Logic symbol

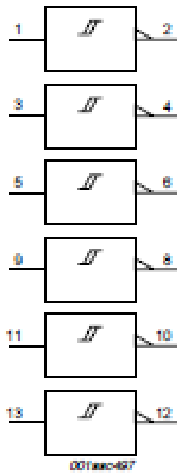


Fig 2. IEC logic symbol

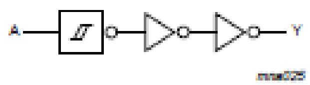


Fig 3. Logic diagram (one Schmitt-trigger)

Pinning information

1 Pinning

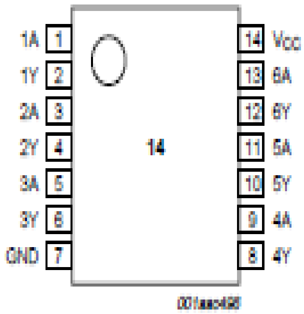
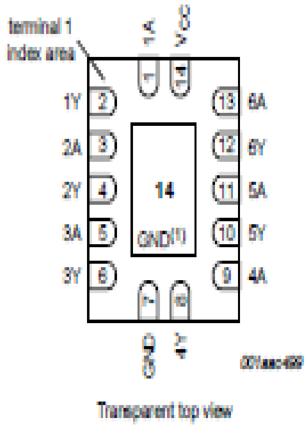


Fig 4. Pin configuration SO14 and TSSOP14



(1) The die substrate is attached to this pad using conductive die attach material. It can not be used as a supply pin or input.

Fig 5. Pin configuration DHVQFN14

5.2 Pin description

Table 2. Pin description

Symbol	Pin	Description
1A	1	data input 1
1Y	2	data output 1
2A	3	data input 2
2Y	4	data output 2
3A	5	data input 3
3Y	6	data output 3
GND	7	ground (0 V)
4Y	8	data output 4
4A	9	data input 4
5Y	10	data output 5
5A	11	data input 5
6Y	12	data output 6
6A	13	data input 6
V_{CC}	14	supply voltage

Data Sheet No. PD60174 Rev.D

International
IOR Rectifier

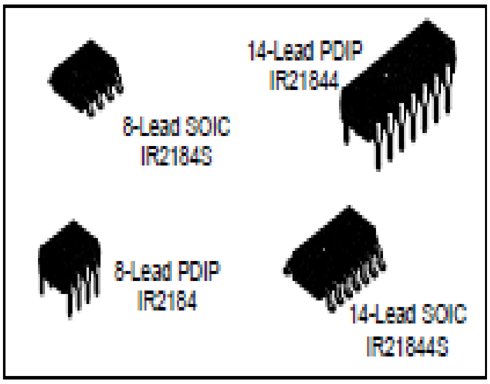
IR2184(4)(S)

HALF-BRIDGE DRIVER

Features

- Floating channel designed for bootstrap operation
  Fully operational to +600V
  Tolerant to negative transient voltage
  dV/dt immune
- Gate drive supply range from 10 to 20V
- Undervoltage lockout for both channels
- 3.3V and 5V input logic compatible
- Matched propagation delay for both channels
- Logic and power ground +/- 5V offset.
- Lower di/dt gate driver for better noise immunity
- Output source/sink current capability 1.4A/1.8A

Packages



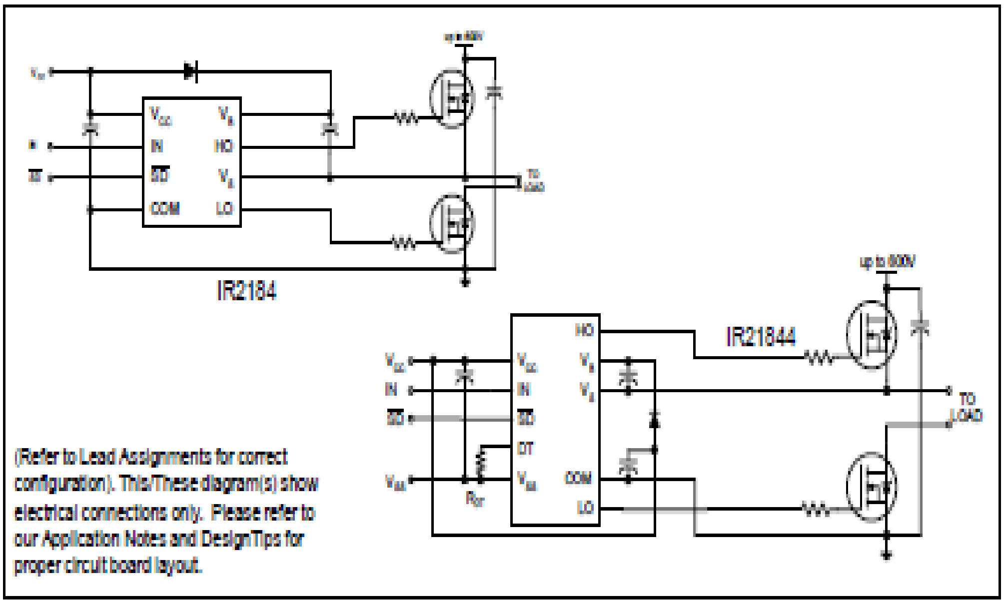
Description

The IR2184(4)(S) are high voltage, high speed power MOSFET and IGBT drivers with dependent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. The logic input is compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 600 volts.

IR2181/IR2183/IR2184 Feature Comparison

Part	Input logic	Cross-conduction prevention logic	Dead-Time	Ground Pins	Ton/Toff
2181	HIN/LIN	no	none	COM	180/220 ns
21814				VSS/COM	
2183	HIN/$\overline{LIN}$	yes	Internal 500ns	COM	180/220 ns
21834			Program 0.4 ~ 5 us	VSS/COM	
2184	IN/$\overline{SD}$	yes	Internal 500ns	COM	680/270 ns
21844			Program 0.4 ~ 5 us	VSS/COM	

Typical Connection



Dynamic Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}) = 15V, V_{SS} = COM, C_L = 1000 pF, T_A = 25°C, DT = VSS unless otherwise specified.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
t_{on}	Turn-on propagation delay	—	680	900	nsec	V_S = 0V
t_{off}	Turn-off propagation delay	—	270	400		V_S = 0V or 600V
t_{sd}	Shut-down propagation delay	—	180	270		
MTon	Delay matching, HS & LS turn-on	—	0	90		
MToff	Delay matching, HS & LS turn-off	—	0	40		
t_r	Turn-on rise time	—	40	60		V_S = 0V
t_f	Turn-off fall time	—	20	35		V_S = 0V
DT	Deadtime: LO turn-off to HO turn-on(DT_{LO-HO}) &	280	400	520		RDT= 0
	HO turn-off to LO turn-on (DT_{HO-LO})	4	5	6	µsec	RDT = 200k
MDT	Deadtime matching = DT_{LO-HO} - DT_{HO-LO}	—	0	50	nsec	RDT=0
		—	0	600		RDT = 200k

Static Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}) = 15V, V_{SS} = COM, DT= V_{SS} and T_A = 25°C unless otherwise specified. The V_{IL}, V_{IH} and I_{IN} parameters are referenced to V_{SS} /COM and are applicable to the respective input leads: IN and $\overline{SD}$. The V_O, I_O and Ron parameters are referenced to COM and are applicable to the respective output leads: HO and LO.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
V_{IH}	Logic "1" input voltage for HO & logic "0" for LO	2.7	—	—	V	V_{CC} = 10V to 20V
V_{IL}	Logic "0" input voltage for HO & logic "1" for LO	—	—	0.8		V_{CC} = 10V to 20V
$V_{SD,TH+}$	$\overline{SD}$ input positive going threshold	2.7	—	—		V_{CC} = 10V to 20V
$V_{SD,TH-}$	$\overline{SD}$ input negative going threshold	—	—	0.8		V_{CC} = 10V to 20V
V_{OH}	High level output voltage, V_{BIAS} - V_O	—	—	1.2		I_O = 0A
V_{OL}	Low level output voltage, V_O	—	—	0.1		I_O = 0A
I_{LK}	Offset supply leakage current	—	—	50	µA	V_B = V_S = 600V
I_{QBS}	Quiescent V_{BS} supply current	20	60	150		V_{IN} = 0V or 5V
I_{QCC}	Quiescent V_{CC} supply current	0.4	1.0	1.6	mA	V_{IN} = 0V or 5V
I_{IN+}	Logic "1" input bias current	—	5	20	µA	IN = 5V, $\overline{SD}$ = 0V
I_{IN-}	Logic "0" input bias current	—	1	2		IN = 0V, $\overline{SD}$ = 5V
V_{CCUV+} V_{BSUV+}	V_{CC} and V_{BS} supply undervoltage positive going threshold	8.0	8.9	9.8	V	
V_{CCUV-} V_{BSUV-}	V_{CC} and V_{BS} supply undervoltage negative going threshold	7.4	8.2	9.0		
V_{CCUVH} V_{BSUVH}	Hysteresis	0.3	0.7	—		
I_{O+}	Output high short circuit pulsed current	1.4	1.9	—	A	V_O = 0V, PW ≤ 10 µs
I_{O-}	Output low short circuit pulsed current	1.8	2.3	—		V_O = 15V, PW ≤ 10 µs

Functional Block Diagrams