

**DESIGN, FABRICATION & EXPERIMENTAL ANALYSIS OF
AUTOMATIC SOLAR TRACKING SYSTEM FOR PARABOLIC
TROUGH COLLECTOR FOR HOT WATER GENERATION**

A Thesis

Submitted for the award of degree

**Master of Engineering
in
CAD/CAM & Robotics**

Submitted by

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(Established under section of UGC Act 1956 vide notification # F-12/84-U.3 of Government of india)

JULY-2013

DECLARATION

I hereby declare that the thesis entitled “**DESIGN, FABRICATION AND EXPERIMENTAL ANALYSIS OF AUTOMATIC SOLAR TRACKING SYSTEM FOR PARABOLIC TROUGH COLLECTOR FOR HOT WATER GENERATION**” is an authentic record of my study carried out as requirement for the award of degree of **Master of Engineering (CAD/CAM & Robotics)** at **Thapar University, Patiala** under the guidance of Mr Devender Kumar, Assistant Professor, Department of Mechanical Engineering, Thapar University, Patiala in July 2013. The matter in this report has not been submitted in part or full to any other university or institute for the award of any other degree.


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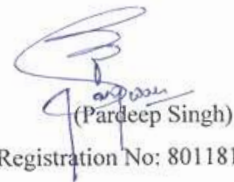
ACKNOWLEDGEMENT

I would like to express a deep sense of gratitude and thank profusely to my guide **Mr. Devender Kumar** for his sincere & invaluable guidance, suggestions and attitude, which inspired me to submit thesis in the present form. His dynamism and diligent enthusiasm have been highly instrumental in keeping my spirits high. His flawless and forthright suggestions blended with an innate intelligent application have crowned my task with success.

I am grateful to **Dr. Ajay Batish**, Professor & Head, MED, **Mr. Sandeep Sharma & Mr. Anirban Bhattacharya**, P.G Coordinators, Thapar University, Patiala for providing me an opportunity to do my project work on the topic of my interest and for providing the facilities for the completion of my work.

I take pride of myself being son of ideal parents for their everlasting desire, sacrifice, affectionate blessings, and help, without which it would not have been possible for me to complete my studies.

I would like to thank Mr. Biju R Varkey, Gianender Kajal, Satbir Singh, which give me full help for doing my electronics work on the same project, and all the members and employees of Mechanical Engineering Department, Thapar University, Patiala for their everlasting support and helping advices. Above all, I express my indebtedness to the *almighty* for all his blessing and kindness.



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INDEX

TITLE	PAGE No.
Certificate	i
Acknowledgement	ii
Index	iii
Abstract	vii
List of figures	viii
List of tables	xii
Nomenclature and abbreviations	xiv
CHAPTER-1: INTRODUCTION	1-16
1.1 Solar Energy	1
1.2 Energy Scenario	1
1.3 Solar Power in India	3
1.4 Solar Radiation on the Earth Surface	3
1.5 Solar Tracker	4
1.5.1 Flat panel Photovoltaic application	4
1.5.2 Concentrated Solar Thermal application	5
1.6 Need for Solar Tracker	5
1.7 Type of Sun Tracker	6
1.7.1 Passive Tracking System	7
1.7.2 Active Tracking System	8
1.7.3 Single axis Tracker	8
1.7.3.1 Horizontal Single axis Tracker	9
1.7.3.2 Vertical Single axis Tracker	10
1.7.4 Double Axis Solar Tracker	10

1.8 Sensors used for Automatic Solar Tracking	11
1.8.1 Light Dependent Resistor	11
1.8.2 Photodiode	12
1.9 Motors	13
1.9.1 Stepper Motor	13
1.9.2 DC Motor	13
1.9.3 Servo Motor	14
1.10 Power Supply	15
CHAPTER-2: LITERATURE REVIEW	17-35
2.1 Performance	17-24
2.2 Design, Material and Economics	24-28
2.3 Application	28-31
2.4 Literature Summary and Gap Analysis	31-34
2.5 Gap Finding	34
CHAPTER-3: METHODOLOGY OF THE WORK	36-37
3.1 Introduction	36
CHAPTER-4: DESIGN AND FABRICATION	38-54
4.1 Design of a prototype parabolic trough concentrator	38
4.1.1 Design parameters	38
4.1.2 Design of prototype PTC using Parabola Calculator 2.0	38
4.2 Fabrication of prototype parabolic trough concentrator	40
4.2.1 Parabolic trough reflective material	41
4.2.2 Glass mirror as concentrator	41
4.2.3 Absorber tube	42
4.2.4 Storage tank	42

4.2.5 Insulations	43
4.2.6 Support structure	44
4.3 Manual tracking system	44
4.4 Automatic tracking mechanism	45
4.4.1 Automatic vertical tracking mechanism	45
4.4.2 Automatic horizontal tracking mechanism	46
4.5 Automatic Tracking System	47
4.5.1 Components of automatic tracking system	47
4.5.1.1 Sensor Casing	47
4.5.1.2 Lenses	48
4.5.1.3 Light dependent resistor	48
4.5.1.4 Transistor 2N2222	49
4.5.1.5 Variable resistance	49
4.5.1.6 Relay	50
4.5.2 Circuit diagram of automatic tracking system	50
4.5.3 Assembled view of the electronics components	51
4.5.4 Working principle of automatic parabolic trough concentrator	52
4.6 Temperature and solar intensity measuring instruments	52
4.6.1 Lux meter	53
4.6.2 Thermometer	53
CHAPTER-5: EXPERIMENTAL ANALYSIS	55-86
5.1 General	55
5.2 Design analysis	56
5.3 Optical analysis	57
5.4 Thermal analysis	57

5.5 Calculation for performance analysis in automatic tracking system	58
5.6 Experimental study of glass mirror with bare copper tube by using manual tracking mechanism	63
5.7 Experimental study of glass mirror with glazed copper tube by using manual tracking mechanism	67
5.8 Experimental study of glass mirror with bare copper tube when the parabola is standing at fixed position	71
5.9 Experimental study of glass mirror with glazed copper tube when the parabola is standing at fixed position	75
5.10 Experimental study of glass mirror with bare copper tube by using automatic tracking mechanism	79
5.11 Experimental study if glass mirror with glazed copper tube by using automatic tracking mechanism	83
CHAPTER-6: RESULTS AND DISCUSSION	87-97
6.1 General	87
CHAPTER-7: CONCLUSION	98-99
CHAPTER-8: FUTURE SCOPE	100
REFERENCES	101-103

ABSTRACT

In this world, everyone needs energy for day to day living cycle. Sources of energy are depleting at a very fast rate. There is need to explore renewable energy sources which are more efficient and give low operating cost. Sun is a source of renewable energy. Solar energy is a basic need of living plants and human being on the earth. It is intermittent in nature, eco-friendly and non-polluting energy. It is freely available throughout the world. Solar energy can be used for hot water generation and direct conversion into electricity and into thermal energy.

A parabolic trough solar collector uses the glass mirror as reflecting material in the shape of parabola to reflect and concentrate the sun radiation towards a receiver tube located at the focus of the parabola. Various solar tracking systems have been developed by various researchers in past decades. A tracking system is still required which can track the sun on real time basis without any geographical data. In the present work an automatic sun tracking system for parabolic trough collector is designed fabricated and experimental analysis is carried out for its feasibility in hot water generation. After experimental work it is found that the automatic sun tracking system gives more efficiency as compare to manual and fixed collectors. In the present work two axis of motion (horizontal and vertical axis) are controlled by using different light detector, DC motors, and gear mechanism. A black painted copper tube is used as an absorber tube and a glazing (glass cover tube of bigger diameter) is provided to minimize the conduction, convection and radiation losses. Water is used as a heat carrying fluid in absorber tube. The concentration ratio of the PTC is 9.66 with aperture area 1.1163 m^2 (without glazing) and 1.035 m^2 with glazing. The maximum temperature of heating water obtained is 85°C while the average temperature of heating water was produced is 68°C . The improvement in efficiency using automatic sun tracking system as compare to manual and fixed position tracking system is 20 to 40%. The results obtained shows that the production of heating water using sun flux is a viable undertaking using automatic solar tracking system. Reduced mass flow rate or with different mass flow rate the efficiency of PTC can further be increased.

LIST OF FIGURES

Figure No.	Title	Page No.
1.1	Solar Radiation on the Earth Surface	3
1.2	Type of Sun Tracker	5
1.3	Passive Tracking System	7
1.4	Active Tracking System	8
1.5	Horizontal Single Axis Tracking System	9
1.6	Double axis Solar Tracker	10
1.7	Light Dependant resistor	11
1.8	Different Type of Photodiode	12
1.9	Stepper motor	13
1.10	DC Motor	14
1.11	Servo Motor	15
2.1	Variation of Collector Water Temperature T_{f_0} with Time	17
2.2	Variation of Useful Heat Gain with Intensity	18
2.3	Solar Geometry	24
3.1	Flow diagram of Methodology	37
4.1	Pictorial view of Parabola Calculator Version 2.0	39
4.2	Pictorial view of PTC with Glass Mirror	41
4.3	Pictorial view of PTC with Absorber Tube	42
4.4	Storage tank in PTC	43
4.5	Different insulations arrangement in PTC	43
4.6	Support structure in PTC	44
4.7	Manual Tracking systems for PTC	45
4.8	Automatic vertical Tracking Mechanism for PTC	46

4.9	Automatic horizontal Tracking Mechanism for PTC	47
4.10	Circular pipe	47
4.11	Lenses	48
4.12	Light dependent resistor	48
4.13	Transistor 2N2222	49
4.14	Variable resistance	49
4.15	Relay	50
4.16	Circuit diagram	50
4.17	Assembly of all parts	51
4.18	Automatic parabolic trough concentrator	52
4.19	Lux Meter for Solar intensity measuring instrument	53
4.11	Thermometer for temperature measuring instrument	53
5.1	Line diagram of PTC with thermometer	55

PERFORMANCE COMPARSION CHARTS

Manual study of glass mirror with bare copper tube:

5.2	Variation of collector water temperature with intensity	64
5.3	Variation of useful heat gain with intensity	65
5.4	Variation of thermal efficiency with intensity	66

Manual study of glass mirror with glazed copper tube:

5.5	Variation of collector water temperature with intensity	68
5.6	Variation of useful heat gain with intensity	69
5.7	Variation of thermal efficiency with intensity	70

Study of glass mirror with bare copper tube when the parabola is standing at fixed position

5.8	Variation of collector water temperature with intensity	72
5.9	Variation of useful heat gain with intensity	73

5.10	Variation of thermal efficiency with intensity	74
	Study of glass mirror with glazed copper tube when the parabola is standing at fixed position	
5.11	Variation of collector water temperature with intensity	76
5.12	Variation of useful heat gain with intensity	77
5.13	Variation of thermal efficiency with intensity	78
	Automatic study of glass mirror with bare copper tube	
5.14	Variation of collector water temperature with intensity	81
5.15	Variation of useful heat gain with intensity	81
5.16	Variation of thermal efficiency with intensity	82
	Automatic reading of glass mirror with glazed copper tube	
5.17	Variation of collector water temperature with intensity	85
5.18	Variation of useful heat gain with intensity	85
5.19	Variation of thermal efficiency with intensity	86
	Manual vs Fixed Position vs Automatic	
6.1	Variation of temperature with time by using different Tracking system in bare copper tube	89
6.2	Variation of temperature with time by using different Tracking system in glazed copper tube	89
6.3	Variation of useful heat gain with time by using different Tracking system in bare copper tube	91
6.4	Variation of useful heat gain with time by using different Tracking system in glazed copper tube	91
6.5	Variation of instantaneous efficiency with time by using different Tracking system in bare copper tube	93
6.6	Variation of instantaneous efficiency with time by using different Tracking system in glazed copper tube	93

6.7	Variation of thermal efficiency with time by using different Tracking system in bare copper tube	95
6.8	Variation of thermal efficiency with time by using different Tracking system in glazed copper tube	95

LIST OF TABLE

Table No.	Title	Page No.
1.1	Direct Power loss due to Misalignment	5
1.2	Comparison of Batteries	16
2.1	Literature Summary	31
4.1	Design parameters for prototype parabolic trough collector	39
4.2	X and Y values for prototype parabolic trough collector	40
4.3	Parabolic trough collector specification after fabrication	54
5.1	Values of design parameters of automatic concentrator	58
5.2	Temperature variation in glass mirror with bare copper tube (manual performance)	63
5.3	Manual performance data in glass mirror concentrator (bare tube)	64
5.4	Temperature variation in glass mirror with glazed copper tube (manual performance)	67
5.5	Manual performance data in glass mirror concentrator (glazed tube)	68
5.6	Temperature variation in glass mirror with bare copper tube when the parabola is standing at fixed position	71
5.7	Performance data in glass mirror concentrator(bare tube) when the parabola is standing at fixed position	72
5.8	Temperature variation in glass mirror with glazed copper tube when the parabola is standing at fixed position	75
5.9	Performance data in glass mirror concentrator(glazed tube) when the parabola is standing at fixed position	76
5.10	Temperature variation in glass mirror with bare copper tube (automatic performance) Dated 20 June, 2013	79
5.11	Temperature variation in glass mirror with bare copper tube (automatic performance) Dated 21 June, 2013	79

5.12	Automatic performance data in glass mirror concentrator (Bare tube) Dated 20 June, 2013	80
5.13	Temperature variation in glass mirror with glazed copper tube (automatic performance) Dated 22 June, 2013	83
5.14	Temperature variation in glass mirror with glazed copper tube (automatic performance) Dated 24 June, 2013	83
5.15	Automatic performance data in glass mirror concentrator (Glazed tube) 24 June, 2013	84
6.1	Values of different performance parameters	87
6.2	Comparison of maximum Temperature by different tracking mechanism	88
6.3	Comparison of Useful Heat Gain by different tracking mechanism	90
6.4	Comparison of Instantaneous Efficiency by different tracking mechanism	92
6.5	Comparison of Thermal Efficiency by different tracking mechanism	94
6.6	Comparison of Overall System Efficiency by different tracking mechanism	96

NOMENCLATURE AND ABBREVIATION

Symbol	Description
A	Collector aperture area, [m ²]
W	Collector width, [m]
	Diameter of absorber tube with glazing, [m]
L	Length of collector, [m]
C	Concentration ratio
	Specific heat capacity of water, [J/kgK]
	Heat removal factor
	Beam or direct radiation, [W/m ²]
	Rim angle factor
	Specular reflectivity of the concentrator
τ	Glass cover transitivity for solar radiation
	Rate of useful heat received from the collector, [W]
	Ambient temperature, [°C]
	Collector water inlet temperature, [°C]
	Collector water outlet temperature, [°C]
	Storage tank water temperature, [°C]
	Initial storage tank water temperature, [°C]
	Outlet temperature of water, [°C]
Dt	Time interval, [h]
	Overall heat loss co-efficient, [W/m ² K]
V	Volume, [m ³]
	Heat loss factor
m	Mass flow rate, [kg/s]
	Instantaneous Efficiency
	Thermal Efficiency
	System Overall Efficiency
	Optical efficiency

PTC	Parabolic Trough Collector
FPC	Flat Plate Collector
CPC	Compound parabolic trough collector

1.1 Solar energy

Solar energy is a high-temperature, high heating power radiant energy source, which has many advantages over other unconventional energy sources. It is a domestic, reliable, strong renewable resource with large not fully formed potential, and it emits essentially none of the atmospheric pollution that are of emergent concern. Solar energy is a very large, unlimited source of energy. The power which is coming on the earth from the sun is approximately 1.8×10^{11} MW [Garg, H P & Parkash, J 1997] and it is larger of times higher than that of other commercial energy sources. Thus, in belief, solar energy can fulfill all the energy requirement of the earth in a regular way. This makes it one of the most talented of the alternative energy sources.

Sun is a source of renewable energy. It is a big sphere of very hot gases, the heat being produced by various kinds of fusion reactions process. The diameter of the sun is 1.39×10^6 km, which is very large while that of the diameter of the earth is 1.27×10^4 km. The mean distance of the sun from the earth is 1.496×10^8 km. Although the size of the sun is big, it makes an angle of only 32 minutes (0.53°) at the surface of the earth. This is because the distance of the sun from the earth is very large. Thus, the beam radiation coming from the sun on the earth is almost inline. The brightness of the sun varies from its center to its edge, depends on the weather. However, from engineering calculations, it is exceptional to assume that the brightness all over the solar disc is same. [Garg, H P & Parkash, J 1997]

1.2 Energy scenario

It is nearly 35 years since the first oil astonish in 1973. Since then the words ‘energy suspense’ continue to dominate the news. By taking these worries now are the matter of climate change. In spite of efforts, renewable sources of energy and other new sources, fossil fuels (coal, oil & natural gas) were developed. While the need for alternative

sources of energy is recognized, no set of alternatives has emerged which can take over the role played by fossil fuels.

In India the energy problem is a very serious matter. After discovery of oil and gases the import of crude oil creates a great problem, because lots of money is invested. Every year the country will spend more than Rs 5000 crores for the import of oil and gases. This amount of money forms a major part of India's import bill. The need for producing energy alternatives is very necessary and many researcher and developer work is already in progress in that direction.

One of the better options is to make more widely use of renewable sources of energy coming from the sun. Solar energy can be used both directly and indirectly. It can be used directly in many thermal applications like drying, heating water of air, distillation, refrigeration, and electricity generation. A second way in which solar energy can be used indirectly is the photovoltaic effect in which solar energy is converted into electrical energy. Thus the energy obtained from the sun is free of cost, and it can be easily converted to any other form of energy.

Thus today, every country completes his energy requirement by various sources. These sources of energy are commercial and non commercial. Fossil fuels (coal, oil & natural gas), hydroelectric power, nuclear power and wind power are come under commercial sources of energy, while wood, animal wastes and agricultural wastes are come under non commercial energy sources. In an industrialized country like USA, energy requirements are fulfilled by using commercial sources of energy, while in less developed country like India, commercial and noncommercial sources are equally used.

In the past few years, it has become obvious that the use of fossil fuel resources are very fast and that the fossil fuels are coming to an end stage. This is because a great use of oil and natural gas. Every person is completely dependent on the commercial sources of energy for living a better life. But it creates large quantity of problems. Perhaps the most serious of these is a dangerous effect on the environment. The combustion of fossil fuels has caused the environment pollution in many areas; because of many industries release

harmful gases in the atmosphere. It is also the main contributor phenomenon of global warming which is now a great issue of concern. [Garg, H P & Parkash, J 1997]

1.3 Solar Power in India

In currently, the capacity of electricity installed in India's is 135 401.63MW. There is a peak power lack of about 10 % and overall power lack of 7.5 %. The 11th plan aim is to add 100 000 MW by 2012 and MNRE has set up aim to add 14500 MW by 2012 from new and renewable energy resources out of which 50 MW would be coming from solar power. The included Energy Policy of India envisages electricity generation installed capacity of 800 000 MW by 2030 and a substantial role would be from renewable energy. This indicates that India's energy requirement in future is very high and solar energy is the best way to fulfill these energy requirements. (Making solar thermal power generation in India a reality – Overview of technologies, and challenges **Shirish Garud, Fellow and Ishan Purohit**, Research correlate, The Energy and Resources Institute (TERI), India). [Garg, H P & Parkash, J 1997]

1.4 Solar radiation on the earth surface

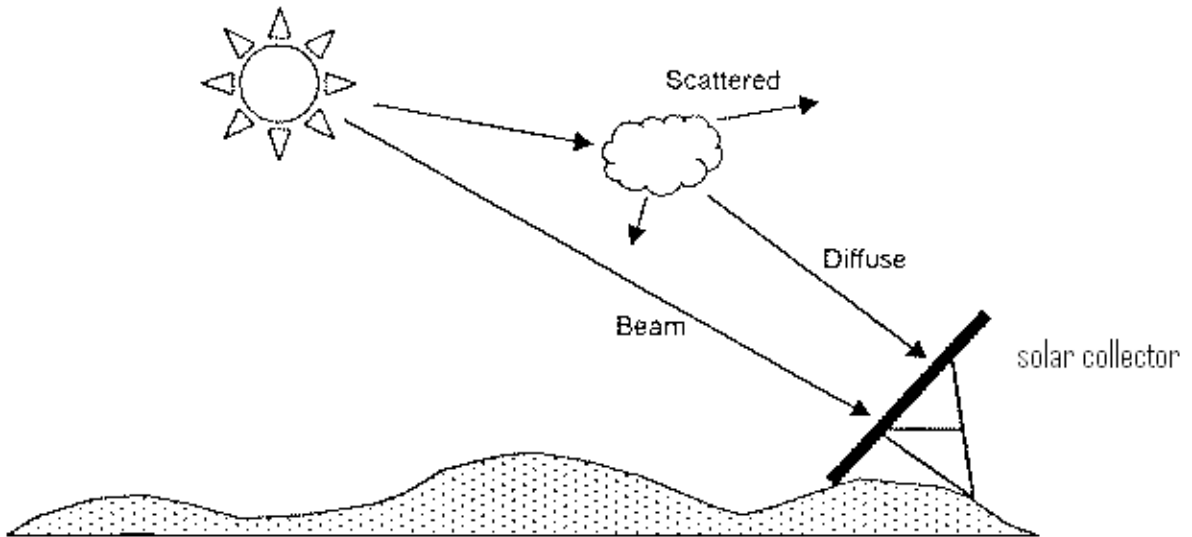


Figure 1.1 [Garg, H P & Parkash, J 1997]

Solar radiation which comes on the earth is received in an attenuation form because it passes to the mechanism of absorption and scattering while received on the earth.

Beam radiation

The radiation which is directly come from the sun on the earth is called beam radiation. These radiations are in line with the sun.

Diffuse radiation

The radiation which is received at the earth surface from all part of the sky's hemisphere (after being subjected to scattering in the atmosphere) is called diffuse radiation.

Total radiation

The sum of the beam and diffuse radiation is called as total or global radiation.

1.5 Solar tracker

- A solar tracker is a device that orients various payloads toward the sun. Payloads can be photovoltaic reflectors, panels, lenses or other optical devices.
- Thus the primary advantage of a tracking system is to collect solar energy for a long time of the day and with the most accurate alignment as the Sun's position shifts with the seasons, as it track the sun in all directions. [Cheema, S S 2012]

1.5.1 Flat-panel photovoltaic (PV) applications

In flat panel photovoltaic applications trackers are used to minimize the angle of incidence between the incoming light and a photovoltaic panel. It increases the amount of energy produced from a fixed amount of installed power generating capacity within standard photovoltaic applications, it is used to judge that trackers are used in at least 85% of commercial installations greater than 1MW from 2009 to 2012. [Cheema, S S 2012]

1.5.2 Concentrated photovoltaic (CPV) and concentrated solar thermal (CSP) applications

In concentrated photovoltaic (CPV) and concentrated solar thermal (CSP) applications trackers are used to enable the optical components in the CPV and CSP systems. The optics accepts the direct component of sunlight in concentrated solar application and therefore must be oriented appropriately to collect power. Tracking systems do not produce energy unless oriented closely toward the sun so that it found in all tracking applications. [Cheema, S S 2012]

1.6 Need for solar tracker

The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel. The table no. 1.1 shows the Direct power lost (%) due to misalignment (angle i).

Table 1.1 Direct power lost (%) due to misalignment (angle i)

Misalignment angle (i)	Direct power lost (%)= $1-\cos(i)$
0^0	0
1^0	0.015
3^0	0.14
8^0	1
23.4^0	8.3
30^0	13.4
45^0	30
60^0	>50
75^0	>75

The sun movement is from east-west through 360° around a day, but the visible portion is 180 degrees during a $\frac{1}{2}$ day period because of perspective of any fixed location. Local horizon effects making the effective motion about 150 degrees by reducing the perspective of any fixed location. A solar panel in a fixed direction between the dawn and

sun set extremes will see a motion of 75 degrees on either side, and thus, on the basis of the table above, will lose 75% of the energy in the morning and evening. The panels are rotated from east and west can help recapture these losses. A tracker which is rotating in the east-west direction is known as a single-axis tracker.

The sun also moves from north-south all over the period of a year at angles of 46 degrees. The same panels set is fixed at the midpoint between the two local extremes will thus see the sun move 23 degrees on either side, causing losses of 8.3%. A tracker that accounts for both the daily and seasonal motions is known as a dual axis tracker. [Cheema, S S 2012].

1.7 Type of sun trackers

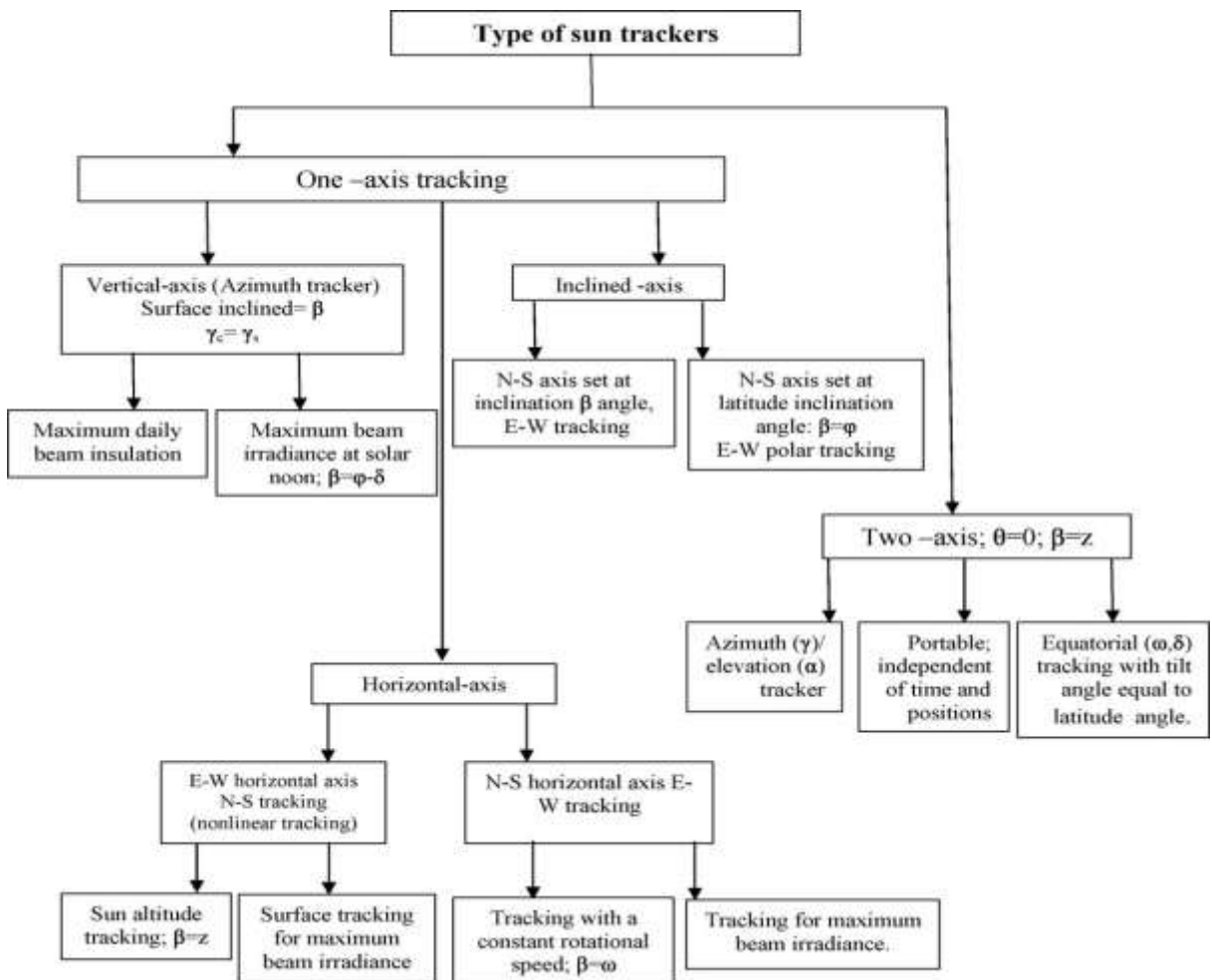


Figure 1.2 [Mousazadeh, H 2009]

1.7.1 Passive Tracking System

The passive tracking system realizes the movement of the system by utilizing low boiling point water. This water is vaporized by the added heat of the sun and the center of mass is shifted leading to that the system finds the new equilibrium position.

Passive solar trackers are based on thermal expansion of a matter (usually Freon). Generally this kind of tracker composed of a couple of actuators working against each other which are the equal illumination of light. The unbalanced forces are used for orientation of the apparatus in that direction, where equal illumination of actuators and balance of forces is restored.

Passive solar trackers as compared to active solar trackers are less complex but work in small efficiency and at small temperatures they stop working. After testing, it has been shown that passive trackers are comparable to electrically based systems in terms of performance. Even though passive trackers are often less costly, yet they have not been widely accepted by consumers.

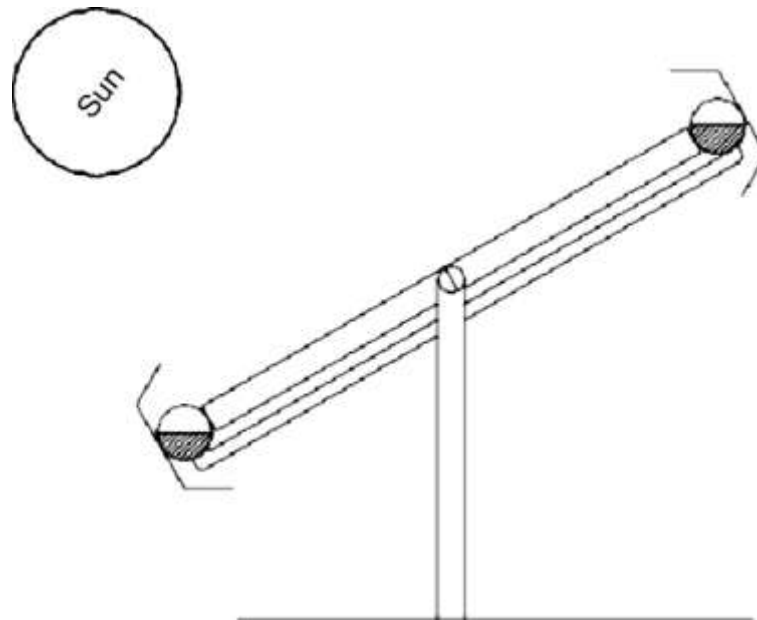


Figure 1.3 A passive solar tracker using two identical cylindrical tubes filled with a fluid under partial pressure [Mousazadeh, H 2009]

1.7.2 Active tracking system

Major active trackers can be categorized as electro-optical sensor and microprocessor based, PC controlled time and date based, auxiliary bifacial solar cell system based and a combination of all three systems. Electro-optical solar trackers consist of at least one pair of anti-parallel connected photo-resistors or PV solar cells which are of equal intensity illumination for both elements, and electrically balanced so that there is either negligible control signal on a driving motor. The auxiliary bifacial solar cell, senses the light and drives the system to the desired position and in the PC controlled date and time based, a PC estimate the sun positions with respect to date and time with algorithms and create signals for the system control.

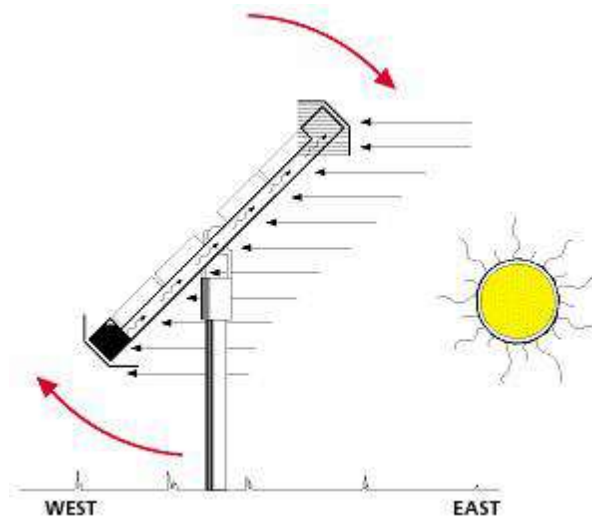


Figure 1.4 Active tracking system [Mousazadeh, H 2009]

1.7.3 Single axis trackers

Single axis trackers have one degree of freedom that acts as an axis of rotation. The rotation of single axis trackers is typically aligned along a true North meridian. It is expected to align them in any cardinal direction with advanced tracking algorithms.

The single axis tracking systems realizes the movement of either azimuth or elevation for a solar power system. The movements of single axis tracking system depend on the technology used on the tracker as well as the space that it is mounted on. For example the

parabolic through systems utilize the azimuthally tracking whereas the many rooftop PV-systems utilize elevation tracking because of the lack of space. A single-axis tracker can only revolve in one plane – either horizontally or vertically. This makes it less complex and generally cheaper than a two-axis tracker, but it is less effective at harvesting the total solar energy available at a site. Trackers use motors and gear trains to direct the tracker as commanded by a controller responding to the solar direction. The motors consume all energy, so one wants to use them only as necessary. [Cheema, S S 2012]

1.7.3.1 Horizontal single axis tracker (HSAT)

The axis of rotation for horizontal single axis tracker is horizontal with respect to the earth. The posts at any end of the axis of rotation of a horizontal single axis tracker can be shared between trackers to lower the installation cost.

Field layouts with horizontal single axis trackers are very flexible. The simple geometry of the tracker means that keeping the entire axis of rotation parallel to one another that is required for appropriately positioning the trackers with respect to each other.



Figure 1.5 A single axis horizontal tracking system [Cheema, S S 2012]

In single axis horizontal trackers, a long horizontal tube is supported with the frame. The axis of the tube is on a north-south line and it rotates on its axis. Panels are fitted on the tube, and the tube will rotate on its axis to track the apparent motion of the sun through the day.

1.7.3.2 Vertical single axis tracker (VSAT)

The axis of rotation for vertical single axis trackers is vertical with respect to the earth. These trackers revolve from East to West over the course of the day. Such trackers are more efficient at high latitudes than are horizontal axis trackers.

Vertical single axis trackers typically have the face of the module oriented at an angle with respect to the axis of rotation. It sweeps a cone that is rotationally symmetric around the axis of vertical rotation as a module tracks. [Cheema, S S 2012]

1.7.4 Double axis solar trackers

Double axis solar trackers have both a horizontal and a vertical axle and so can track the Sun's apparent motion exactly anywhere in the World. Figure 1.6 shows a Solar Tracker using horizontal and vertical axle.



Figure 1.6 Double axis solar tracker [Cheema, S S 2012]

Double axis solar tracking system can trace the Sun at any location with the help of geographical data of that location.

This type of tracking system is used to manage astronomical telescopes, and so there is various software's available to automatically predict and track the motion of the sun across the sky. The efficiency of the solar panels can be increased by 30-40% by tracking

the sun. The dual axis tracking system is also used for concentrating a solar reflector toward the concentrator on heliostat systems.

Dual axis trackers as shown in the figure have two degrees of freedom that act as axes of rotation, as the name suggest, it can rotate simultaneously in horizontal and vertical directions, and are capable to trace the sun at all times in any location.

There is need of highly capable processing system as well as geographical data of every location. It also need to be calibrated for 365 day of a year, as time of Sun rise, Sun set and elevation changes every day, everywhere in the world.

To overcome this limitation, there is need of simpler and easy to maintain cost effective way to track the Sun for the whole day and for every season throughout the year.

1.8 Sensors used for Automatic Solar Tracking

A sensor is a mechanism that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

1.8.1 Light Dependent Resistor

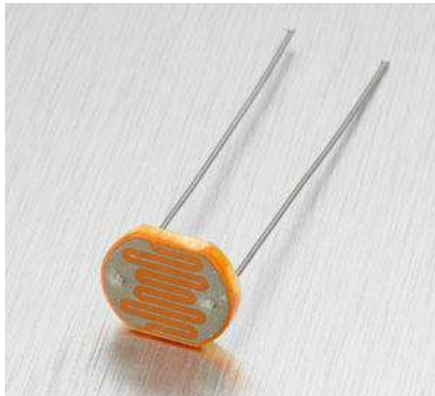


Figure 1.7 Light Dependent Resistor (LDR) [Siew, H W 2008]

Light Dependent Resistor (LDR) is made of a high-resistance semiconductor. It can also be known as photoconductor. If the light fall on the device is of the high frequency, photons are absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct

electricity, thus lowering resistance. Hence, Light Dependent Resistors (LDR) is very useful in light sensor circuits. LDR is very high-resistive power, sometimes as high as $1000\ 000\Omega$, when the resistance is drops dramatically by illumination of light.

1.8.2 Photodiode

Photodiode (BPW34) is a light sensor which has a high speed and high responsive silicon PIN photodiode in a miniature flat plastic package. The design of the photodiode is responsive to optical input. Due to its water clear epoxy, photodiode is sensitive to visible and infrared radiation. The big active area combined with a flat case gives a high sensitivity at a wide viewing angle.



Figure 1.8 Different types of Photodiodes [Siew, H W 2008]

It can be used in either zero bias or reverse bias. In zero bias, light which is fall on the diode causes a voltage to develop across the device, carry a current in the forward bias direction. This is known as photovoltaic effect, and is the basis for solar cells - in fact a solar cell is just a large number of large, cheap photodiodes. Diodes usually have very high resistance when reverse biased. That resistance is reduced when light of an appropriate frequency shines on the junction.

In this way, a reverse biased diode can be used as a detector by monitoring the current running through it. Circuits related on this effect are more sensitive to light than ones based on the photovoltaic effect.

1.9 Motors

Motor are used to drive the tracking system with the movement of the sun. Some of the motor which are available in the market are explain below.

1.9.1 Stepper Motors

Stepper motor has relatively limited power which means that wheel spin will not be a problem. It has not fast movement but yet it will work. In this, two signals are used to operate the driver chips. One signal is used to determines the direction of rotation of the motor, plus for forward and minus for backwards. The other is used to moves the stepper by one step each time it goes from minus to plus.



Figure 1.9 Stepper motor [Siew, H W 2008]

Stepper motors move in steps, 200 or 400 steps per revolution to be precise. To move them, the stepper driver has a smooth pulse. If the pulse timing is out condition, the motor would just stop and not move. They can also produce precise and accurate motor rotation if the correct motor driver firmware signals are obtained.

Due to slow movement, it has a high tendency for Sun tracing, and it gives a very precise step by step movement. But the cost of this motor is very high.

1.9.2 DC Motors

DC motors are cheaper to buy, and simple to drive but they need feed-back sensors to control of the speed.



Figure 1.10 DC Motor [Siew, H W 2008]

It is essential to detect the rotation of the wheels, usually by means of sensors are controlled better by pulling the motor supply that uses less battery power than the analogue methods. It has a low inertia and fast speed, but cost is added for controlling of the motor movement.

The advantages of the DC motor are the torque and their speed is easier to control. The disadvantage of DC motors is that they consumed large amounts of power. They would spent the battery power in a short time and power saving techniques must be employed to ensure the mouse do not stop halfway while navigating. It is also prone to dust and harder to maintain.

1.9.3 Servo Motors

Servos motor contain a small DC motor, a gearbox assembly and some control circuit, and feed on the voltage of 5 volts at about 100mA maximum, and on 10-20mA when it is idle. They have a three-wire connector, one common wire (0 volt, usually black), one +5v wire (usually red), and one signal wire. In normally use they are controlled by pulses of about 1 to 2 milli-seconds at a repetition rate of about 50 per second.

A short pulse drive the servo to one end of the travel, a long pulse makes the servo to drive at the other end, and a medium pulse puts it somewhere proportionally between these two pulse. Some servos have gear mechanism that allows the servo to rotate continuously. This type of method needs the servo to have a feedback potentiometer used by internal circuits to measure the position of the output shaft.

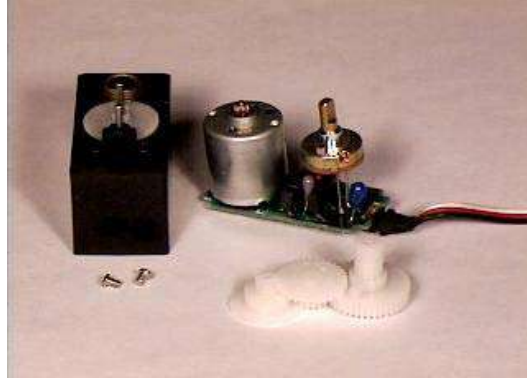


Figure 1.11 Servo Motor [Siew, H W 2008]

If it is disconnected and the wires carried to an external pre-set potentiometer, the servo will move continuously in one direction if fed with short pulses and vice-versa.

If there are no pulses, the servo motor will stop. It is used to move the Solar Tracker Eastward and Westward. The pulses have its at normal TTL levels. The speed is not greatly affected by the pulse repetition rate, as long as it is over about 30 per second. These pulses can easily be provided by an output port of just about any computer, for occurrence the data or control lines of a printer port or a serial port, or a easy addressed latch added to the memory circuits.

1.10 Power Supply

The power supply of the solar tracker is also a considered when designing. They would have to supply the power to the motor, sensor and the interface card. Although there are some other electric power sources available, batteries is the best source for the Solar Tracker.

To make sure the proper operation of all circuitry and their components, a voltage regulation scheme must be employed for providing power.

The table 1.2 shows the comparison of the different type of batteries available.

Table 1.2 Comparisons of Batteries [Siew, H W 2008]

Battery	Advantage	Disadvantage
Alkaline	Alkaline batteries are popular for small electronic devices. These batteries have a high energy density. They are usually quite inexpensive.	Alkaline batteries have high internal resistance and it is not possible to release energy at a fast rate. Alkaline batteries output voltage continues to drop linearly as the battery discharges with a linear slope.
Nickel Cadmium	Nickel cadmium batteries represent the majority of rechargeable batteries. The internal resistance of nickel cadmium batteries is small, making these batteries efficient at fast discharging.	The capacity of the NiCd batteries is recharged without first completely being discharged. NiCd batteries also have a relatively low energy-density.
Nickel Metal Hydride	Nickel Metal Hydride batteries have twice the energy-density of NiCd batteries. For the same size and same mass, a NiMH battery stores twice the amount of energy.	NiMH batteries lose their charge faster than other types of batteries. They also cannot be stored for more than days at a time.
Lithium-ion	Lithium-ion batteries are used in many high end cordless and rechargeable devices.	Although Li-ion batteries seem very suitable for robotics, Li-ion batteries are not designed for continuous high drain rate.

The literature review is categorized on the basis of

- 2.1 Performance
- 2.2 Design, Materials and economics
- 2.3 Application

2.1 Performance

Arasu, A V *et al.*(2006) concluded the performance of a new parabolic trough collector hot water generation system with a well mixed hot water storage tank is investigated. The storage tank water temperature is increased from 35 °C at 9.30 am to 73.84 °C at 4.00 pm when no heat loss is occur from the storage tank. During the collection period the average beam radiation is 699 W/m². The useful heat gain, the collector instantaneous efficiency, the energy absorb by the storage tank water and the efficiency of the system are varied with respect to the beam radiation.

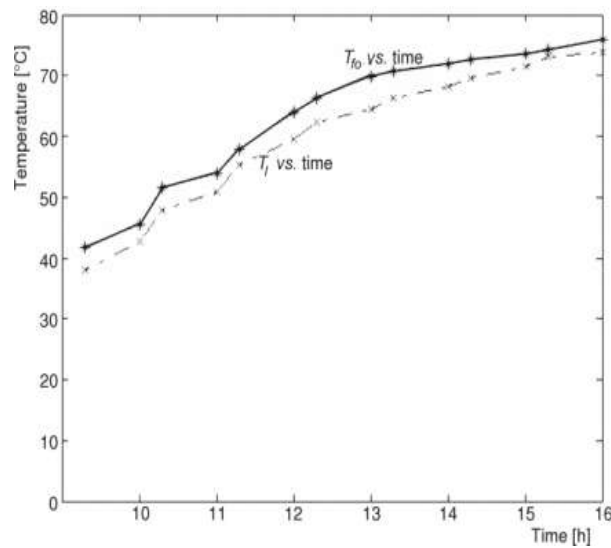


Figure 2.1 Variation of collector water temperature, T_{fo} , with time

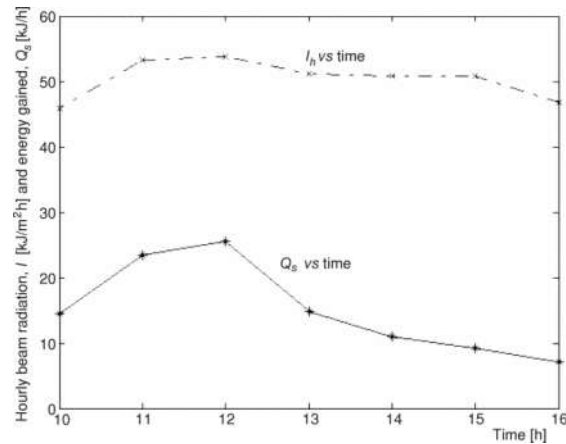


Figure 2.2 Variation of Useful Heat gain with intensity

Khlaichom, P et al.(2007) concluded the high-concentration solar requires the sun to be tracked with great precision for maximum output voltage. This paper trend in solar concentrator tracking system is to use an open-loop local controller that computes the direction of the solar vector based on geographical location and time. But it is not sufficient accuracy because it has error from computing the sun's position, mechanical, controller systems and installation. The genetic algorithms (GA) are one technique for solving these problems. In this research, Genetic algorithm increases the accuracy of solar tracking system by using wolf's theory that receives maximum solar radiation, so the system becomes on-line. The system will manage machine to positions of each answer population from an initial set of accidental solutions and estimate by measure voltage from sensor, then produce the next generation by using intersect operator, mutation operator and selection. In the experimental, statistical method has a great for finding the best parameters of GA. The experiment result shows that the performance increases about 7.084% by using genetic algorithm.

Lorenzo, E et al.(2002) presented that Solar tracking is used in large grid-connected photovoltaic plants to increase solar radiation collection for reducing the cost of delivered electricity. Single vertical axis tracking, also called azimuth tracking has a capacity for energy gains up to 40%, as compare with optimally tilted fully static arrays. This paper examined the theoretical aspects associated with the design process of azimuth tracking, by taking into account of shadowing between different trackers and back-tracking

features. Single, horizontal, North–South-oriented axis tracking system is associated with flat-plate modules represent by far the most extended tracking solution in current PV plants. Because of their intrinsic lack of shadowing in the North–South direction, single tracking devices can be drive large surfaces and due to the horizontal axis position, wind loads tend to be relatively low. It involves a particularly simple and strong mechanical construction, which is a great advantage of this type of tracking.

Helwa, N H *et al.*(2007) has concluded that the output energy from any solar energy system depends on the solar energy input to that system. Solar energy input depends on the type of tracker, because every tracking system has distinct capacity of gaining the solar radiation. A practical study was carried out on different solar tracking systems. The layout of these systems consist of a fixed system facing south and tilted 40° a vertical-axis tracker, a 6° tilted-axis tracker, and a two-axis tracker. All the trackers depend on the microprocessor based controlled systems, and every system has photovoltaic arrays for electric energy generation. The performance of the different systems is based on a complete year input of solar radiation and the electric power output from them. The study also consists of the effect of some operating parameters on the tracking operation. This study showed that the collected solar energy as well as the electrical output energy of the tracking solar systems is more than that of the stationary system. These gains of solar radiations are higher in the case of the two-axis tracker and decrease gradually from the vertical-axis tracker to the tilted-axis tracker. Some of the important and concluded lines are given below:

- The vertical axis tracker receives 18% more annual solar radiation as compare with the fixed-tilt system and generates 21% more output power in 9 months.
- Solar system tracking around a tilted-axis increases its annual solar radiation by 11% as compare with the fixed-tilt system, while the combination of the tilted-axis tracker and the vertical axis tracker receives 57% more annual solar radiation input and produces 31% more output than the fixed-tilt system.
- Solar system movement around two perpendicular axes increases its radiation received capacity by 30% over the fixed-tilt system.

- The microprocessor solar trackers follow the sun in large range and show small pointing error, but they require more care in installation of the reference position sensors.
- The system output is influenced by the effect of the tracking error. It depends on several parameters, such as type of application (flat plate or concentrated), tilt angle of the system plane, season, and time of day.
- The tracking accuracy is directly proportional to the electrical power consumed by the solar system.

Chicco, G *et al.*(2008) presented the performance of grid connected photovoltaic (PV) systems with parallel-connected converters. This paper concentrates the two paths for energy production. The first part concerns the evaluation of the energy production in Sun-tracking configurations, comparing their performance according to fixed PV systems. The second part is related to the harmonic characteristics of a number of converters in PV plants of various sizes. The PV plants of different types (in fixed or Sun-tracking configurations) are increasing diffusion and sizes (from a few kW to several MW) with inverter connection to the grid are requiring detailed analyses concerning their aggregation and the assessment of their performance. The Sun-tracking configurations are capable to provide significant increase in the energy production over fixed systems of equivalent characteristics, provided that the availability of the moving parts can be guaranteed and that mutual shading conditions are avoided. The harmonic and inter harmonic summation ratios have been used to represent the effect of harmonics and inter harmonics of different orders to the assessment of the total current of the PV aggregation. The use of a semi empirical approach for harmonic summation seems more suitable than other statistical techniques in order to create a reference model for evaluating the total current.

Stern, M *et al.*(2010) The overall goal of this PVMAT Phase 4A1 work effort by Utility Power Group ("UPG") was to substantially reduce the total installed cost of utility-scale grid connected photovoltaic ("PV") power systems. PV power systems generate electricity via the direct conversion of sunlight into electrical energy and can serve as an environmentally benign and domestically secure source of electricity for utility grid

connected peak or intermediate load applications. Considering that almost 700,000 mega watts (MW) of electricity generating capacity exists in the United States alone, PV power systems have only negligibly penetrated the electricity generation market. The dominant factor limiting the use of PV power systems in grid-connected applications, today is the capital cost of the total installed system with respect to the annual kilowatt-hours of energy generated. The focus of UPG's work effort was on BOS component manufacturing technology, which essentially involved all PV power system engineering, manufacturing, assembly and construction tasks from the receipt of a PV module to the delivery of grid-connected electricity. Working with Siemens Solar Industries (Camarillo, California) to optimize the design of PV modules for power systems applications, UPG's goal was to obtain and demonstrate significant cost reductions in the installed cost of PV power systems. Single-axis solar tracking, which provides over 20% more energy in a typical year than a fixed-axis PV system, was selected as the optimum array configuration upon which the overall design was based.

Naidoo, P *et al.*(2002) conclude that tracking is particularly important in solar energy collection systems that operate under concentrated sunlight. The aim of this research paper is to test the solar-to-thermal energy efficiency of a tracking line-focus parabolic trough solar collector (PTSC). This is determined by measuring the temperature rise of water as it flows through the receiver of the collector when it is properly focused with the sun. The thermal efficiency is a function of intercept factor in case of PTSC, which in turn depends on the accuracy with which the collector follows the sun. Accurate control of the collector is therefore crucial to the maximizing of a PTSC's thermal efficiency. Given the varying demands of different operating regimes required for proper operation of the solar collector, different modes of control will form an integral part of the project to optimize tracking accuracy and thereby thermal efficiency as well. In the fixed rate control mode the variable speed drive is programmed to rotate the trough at a constant rate based on the movement of the sun. In the PSA control mode an algorithm is defined by means of mathematical formulae, generating a variable data signal to the drive based on the position of the sun on the X, Y, Z axis. In both these modes position feedback is not necessary but will be used for reference purposes and not necessarily for actual

control. However, in the fuzzy control mode the position detection, wind speed and the fluid circulation temperature will be essential to determine the position of the trough.

Duarte, F *et al.*(2010) presented that there are actually several solutions for two axis solar tracking systems using electromechanical devices, in which a controller detects the Sun apparent position, and controls the position of the body supporting the panels toward the sun by enabling the engines motion. This work, related to the solution of two axis solar tracking system based on solar maps, which can find out the exact apparent position of the Sun, by the latitude's place, thereby avoiding the need to use sensors or guidance systems. To accomplish this, it is used a low-power microcontroller, with programming, to control two electric motors to ensure that the panels supporting structure is always oriented towards the sun. A two axis solar tracker system can increase the energy conversion by 40%, being a suitable solution to increase the electrical energy output. It seems that a major obstacle to its use is the cost, basically due to the price of the sensors applied to detect the Sun apparent position, and to the control system (mainly with PLCs). Studies concerning the Sun apparent movement concluded that it is possible to predict the relative position of the Earth with accuracy and the place, day and every hour. This position is described in solar maps, for each location (defined by the location's latitude). Microcontrollers can be used in order to control the electric motors. Using the microcontrollers with programmed solar maps for each location (latitude), and defining the date and hour, it is possible to control the angular position of the electric motors drive shafts. The aim of this work consists on the development of a two-axis electromechanical system for sun tracking (detect Sun apparent position), based on solar maps data, with a low energy consumption and lower final cost than the systems available on market.

Lee, C Y *et al.*(2009) The output power produced by high-concentration solar thermal and photovoltaic systems is directly related to the amount of solar energy gained by the system, and it is very necessary to track the sun's position with a high degree of accuracy. A lot of systems have been proposed to facilitate this task over the past 20 years. This paper examine by providing a high level overview of the sun tracking system field and then describes some of the more significant proposals for closed-loop and open-loop types of sun tracking systems. Such systems are based on the design of the solar collector

to collect the sun's energy and to convert it into either electrical power or thermal energy. The paper contains many studies regarding the use of solar collectors to implement such applications as light fixtures, window covering systems, cookers. In general, the power developed in such applications depends fundamentally upon the amount of solar energy captured by the collector, and thus the problem arises of developing tracking system capable of following the trajectory of the sun throughout the course of the day on a year-round basis has received significant coverage in the literature.

Alkilani, M M et al.(2011) designed a multi dimensional solar tracking system and fabricated, The designed tracking system is very beneficial because the component used in the system is nearby available with low cost. Moreover, it is not any requirement for connection to the transmission and distribution lines and minimal need for maintenance and monitoring. This paper is reported that the sun tracker (two dimensional) has increased the overall efficiency of the solar installation by over 40%. Designed simplicity, Low cost and material availability will make the designed tracking system more effective and acceptable in the market. This tracking system is simple and easier than any other tracking system with minimum cost because only simple sensor (LDR) and driver circuit (OA) is used which is available with low in cost. This device does not need auxiliary power and may adjust automatically depending on the direction of the sun. With the designed sun tracker, it is possible to get substantially more power from each PV panel on collector and this increase in power results with lower cost per watt.

Konar et al.(2011) A microprocessor-based automatic position control scheme has been designed for controlling the azimuth angle of an optimally tilted photovoltaic flat type solar panel or a cylindrical parabolic reflector to get the illuminating surface appropriately positioned for the collection of maximum solar irradiance. The idea presented results in considerable saving in power and is independent of the geographical location of the site of erection or temporal variations in environmental parameters. Efficient collection of maximum solar irradiance (**MSI**) on a flat plate type photovoltaic solar panel [i] or a cylindrical parabolic solar reflector requires adjustments of two parameters of the energy collecting surface namely the angle of azimuth, (Ψ) and the angle of tilt(α) of the surface to be illuminated as shown in Fig. 2.3. As the elevation

angle of the sun remains almost invariant in a month and varies little (latitude 10°) in a year, there is no need for automatic adjustment of the tilt angle. A single axis position control scheme is sufficient for the collection of **MSI** on a solar energy collector.

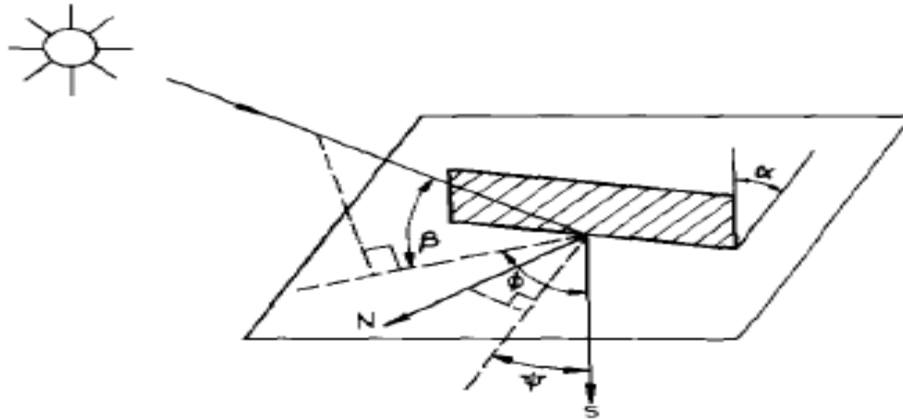


Figure 2.3 Solar geometry

Roth, P et al.(2003) concluded an electromechanical system to follow the position of the sun was designed. It allows the automatic measurement of direct solar radiation with a pyranometer. This operates automatically, guided by a closed loop servo system. The position of the sun is sense with the help of photo detector and two small DC motors move the instrument platform keeping the sun's image at the center of the four-quadrant photo detectors. In the cloudy season when the sun is not appear, the position of the sun is calculate by a computing program and takes control of the movement, either the detector can sense the sun again.

2.2 Design, materials and economics

Thomas, A et al.(1992) studied that design parameters of a PTC can be geometric and functional. The geometric parameters of a PTC can be its aperture width and length, rim angle, focal length, diameter of receiver etc. The functional parameter can be its instantaneous efficiency, optical efficiency and overall thermal efficiency. These parameters are mainly affected by properties of material and optical errors associated with system. The instantaneous efficiency of a PTC can be calculated from an energy

balance on the receiver tube. The instantaneous efficiency of the system is defined as the rate at which useful energy is delivered to the working fluid per unit aperture area divided by the beam solar flux at the collector aperture plane.

Zeroual, A *et al.*(2007) presents an electronic sun-tracker system which uses electro-optical sensors for sun finding and a microprocessor controller unit for data processing and for control of the mechanical drive system. The system allows solar energy collectors to follow the sun position for optimum efficiency. It has a modular type structure which facilitates its application to different systems without great modifications. The electro sun tracking system has been applied to control a water heating parabolic solar system for domestic uses. A lot of parameters have been controlled for system security such as pressure, temperature and wind velocity. The system has been experienced for a long period in variable illumination. The results are shown that it operates satisfactorily with high accuracy. All the limitations mentioned in both electro-optical and microprocessor controllers have been corrected. This system combines the best characteristics of the two previous trackers. As soon as the system is switched on, it automatically finds the position of the sun and aligns itself with its control unit. It has the capability of adjusting the position of the collector from end-of-day position to that for operation early the next day; adjusting for intermittent clouds, and adjusting to a position where the collector can best withstand very high winds without damages. It also enables system performance to be analyzed.

Anderson, T N *et al.*(2008) presented the concern growing over the environment and resource use has been greater emphasis placed on sustainability, particularly in the growing environment. One of the important key points of sustainable urban environments is the need for an increase in the densification of the population. It would have been probable to have a photovoltaic array and solar water heater side-by-side for a free-standing house hold, this may not be attainable in a high-density living situation. As a counter point to this matter, the design of a novel combined photovoltaic for building integration (BIPVT) solar collector is analyzed and discussed. The panel has a greater efficiency per unit area, as compare to an array of photovoltaic panels in combination with solar thermal panels. In addition of this panel can be used for integrating water

heating, electricity generation and facade elements it is possible to reduce the complexity associated with traditional solar installations while also achieving an architecturally responsive appearance. As such the BIPVT is preferably suited to environments where frontage space with suitable solar access is limited, or where many numbers of people share a single building.

Arasu, A V *et al.*(2007) described the design and manufacture of a smooth 90 rim angle fiberglass reinforced parabolic trough for parabolic trough collector hot water generation system by hand lay out method in this paper. The paper concluded the following points. The design and manufacture of a smooth 90 rim angle fiber glass reinforced parabolic trough for parabolic solar collector is presented. The cost of the fiber glass reinforced parabolic trough is 48US\$ per square meter of aperture area and the cost of the wooden mould is 67US\$.

Bakos, G C *et al.*(2000) observed that parabolic trough are the preferred type of a collector used for steam generation due to their ability to work at high temperatures with high efficiencies. The results formed from a simulation program, shows the variation of collector's efficiency as a function of the heat transfer fluid flux, pipe diameter and solar radiation intensity and active area of the PTC, are presented. This paper concluded the following points

1. When the flux of the heat transfer fluid is increasing, the efficiency is improving. Also the efficiency drops as the pipe length is increased.
2. The efficiency increases as the pipe diameter is reduced. This result was expected because the smaller diameter led to a greater solar radiation density on the active area of the pipe.
3. The efficiency increases with the increase of the mirror's active diameter and the intensity of solar radiation respectively.

Almanza, R & Correa, G *et al.*(2000) with the aim of developing a parabolic trough concentrator with first surface solar mirrors made over coated soda-lime glasses with concave shape type geometry. In order to cover all the surface of the concentrator, whose

size measurement were 2.37m of aperture and this product works up to 8003C with a minimum deformation when it has been set and hardened. In order to sag the coated glasses, they were introduced in a furnace up to 6003C for about 2 h. Mirrors were made by using sputtering technique with planar magnetron. The specular reflectance of the mirrors was around 86%. The field test of focusing such a concentrator gave a size focus of about 5.08 cm, where over 90% of reflected beam solar irradiance arrived on a simulated pipe receiver with this diameter 1.14m long, 16 mirrors were built with sizes of 0.3 to 0.6m and they were put together like a mosaic set.

Saxena, A K *et al.*(2010) A microprocessor based solar Tracking controller is designed and fabricated in addition to tracking the controller is capable acquiring photovoltaic and meteorological data from a photovoltaic system and controlling battery / load. These features are extremely useful in autonomous PV system installed in remote areas for system control and monitoring. Solar tracking can be built in closed loop and open loop modes and the controller can provide either 6 PWM data signals for 3 phase electricity, 50 Hz AC motor or 4 step signals for a stepper motor. The change in sun position is monitored and the convertor is maintained normal to the incident radiation for optimum performance.

Inspira, A *et al.*(2009) presents a novel sun tracking strategy for photovoltaic concentrators. This can be integrated in the so called hybrid strategies, which built around a calculated sun ephemeris core, add different types of error correcting routines to compensate on the one hand for timing drifts, and on the other for self characterization errors due to a faulty installation, assembly, or manufacturing, or in the time evolving side those caused by stress bending or landslides, which ultimately blur the “picture” the tracking control has of its tracker. Hybrid sun tracking strategies intend to combine the best of both open-loop ephemeris computing, and closed loop sun pointing sensor based controllers, while avoiding their problems. By using an open-loop sun primary acquisition phase, hybrid controllers wake and stow at specified positions and times and their effectiveness is immune to sunshine conditions or drifts in sensor calibration, thus avoiding the problems in acquiring and locking onto the sun that occur with closed-loop systems. By using a closed-loop error correction phase, hybrid controllers avoid the open-

loop controller problems of needing accurate alignment, assembly, and time information. These error correction routines usually take as feedback signal the array's power output thus relying on the obvious equivalence between precise sun pointing and maximum generation.

Comsit, M *et al.*(2007) presented the development of the solar radiation conversion systems is focused mainly on aspects related to materials development and solar energy conversion processes. In the design procedure of the solar trackers the input data is the direct solar radiation that may be converted in thermal energy (by using solar collectors) or electrical energy (by use of the photovoltaic panels). The competitiveness of the solar energy conversion system on the market deals with their efficiency and an alternative solution for improving their efficiency is the use of the tracking systems so called "solar trackers". According to the scientific literature of the system, by raising the incident radiation rate with solar trackers, in order to maximize the direct degree of solar radiation collection, the efficiency of the solar radiation system may be increased up to 50%.

2.3 Application

Kalogirou, S A *et al.*(2004) presented a survey of the various types of solar thermal collectors and applications. Initially, an analysis of the environmental problems related to the use of conventional sources of energy is presented and the benefits offered by renewable energy systems are explained. The historical is based of the various types of collectors including flat-plate, evacuated tube, compound parabolic, parabolic trough, Fresnel lens based, parabolic dish type and heliostat field collectors. It is followed by an optical, thermal and thermodynamic examination of the collectors and an explanation of the methods used to evaluate their performance. The applications of the various types of collectors are accessible in order to show the reader of extent in order of their applicability. These contain solar water heating, which comprise thermo syphon, integrated collector storage, air systems, direct and indirect systems, space heating and cooling, which include, space heating, air and water systems and service hot water, and heat pumps, refrigeration, industrial process heat, which include air and water systems and steam generation systems, thermal power systems, which comprise the parabolic

trough, power tower type and dish systems based, solar furnaces, and chemistry applications. It can be seen solar energy systems can be used for a wide range of applications and provide significant benefits, therefore, they can be used whenever possible.

Rubio, F R *et al.*(2007) The application of high concentration solar cells technology allows a very significant increase in the quantity of energy collected by solar arrays per unit area. Though, to make it possible, more severe specifications on the sun pointing error are required. In fact, the presentation of solar cells with concentrators decreases drastically if this error is greater than a small value. These provisions are not fulfilled by simple tracking systems due to different sources of errors (e.g. small misalignments of the structure with respect to geographical north) that appear in practice in small cost, domestic applications. This paper presents a control application of a sun tracker that is able to follow the sun with high accuracy without the necessity of either a precise procedure of installation or recalibration. A hybrid type of tracking system that consists of a combination of open loop tracking strategies based on solar movement models and closed loop strategies using a dynamic feedback controller is presented. Energy saving factors is taken into account, which implies among other factors, the sun is not tracked with the same precision, to prevent energy overconsumption by the motors. Simulation and experimental outcome with a low cost two axes solar tracker are exposed, included a comparison between a classical open loop tracking strategy and the proposed hybrid one.

Scrivani, A *et al.*(2007) examined the concept of utilizing trough type solar concentration plants for water production, remediation and waste water treatment. This presented study is intended to find applications of the solar trough concentration technology beyond heat and refrigeration. A number of possibilities have been identified are related to clean water production by processes such as solar distillation, and waste processing. The fresh water thus obtained can be used for human consumption, but the free heat produced by trough plants makes for an easy way to obtain irrigation water from waste, refuse and landfills. The possibility of obtaining refrigeration without the use of electrical power opens up further possibilities for obtaining water, even from thin air. The possibility of utilizing this water for irrigation is a concrete step in the favour of

agriculture in Mediterranean countries. The system is a low cost, no pollution, and alternative to incineration.

Qiblawey, H M *et al.*(2007) describes several desalination technologies in commercial and pilot stages of growth. The prime focus is on those technologies suitable for use in remote areas, which could be integrated into solar thermal energy systems. The use of solar energy in thermal desalination processes is one of the most promising applications of the renewable energies. Solar desalination can directly use solar energy to produce distillate directly in the solar collector, or indirectly; combine conventional desalination techniques, such as multistage flash desalination (MSF), vapor compression (VC), reverse osmosis (RO), membrane distillation (MD) and electro-dialysis, for heat generation. Direct solar desalination system compared with the indirect technologies requires large land areas and has a relatively low productivity. It is though competitive to the indirect desalination plants in small-scale production due to its relatively low cost and simplicity.

Blake, D M & Kearney, D *et al.*(2002) established the development of a thermal storage option and increasing the operating temperature for parabolic trough electric systems could significantly reduce the level of electricity cost (LEC) as compared to the current state of the art. Both improvements need a new heat transfer fluid if a direct storage system is to be used. The properties of a fluid that can be used for both heat collection and storage require a very low vapor pressure at the hot side operating temperature. This requirement can almost certainly only be met by an ionic fluid. Further, the piping layout of trough plants dictates that the fluid not be allowed to freeze which requires extensive insulation and heat tracing unless the fluid has a freezing point $<25^{\circ}\text{C}$. A recent study by Kearney and associates under subcontract to Sun lab has explored the potential for use of inorganic nitrate salts that freeze at about 120°C and documented the advantages of storage and higher operating temperature. As part of that study, the LEC achievable if an “ideal” fluid having the above properties was documented. It seems likely (but not certain) at present that this ideal fluid will have to be found among organic rather than inorganic salts. This paper summarizes the results of the first year of searching for heat

transfer and storage fluids in this new domain and identifies the key issues that must be addressed in the development of a new fluid.

2.4 Literature summary and gap analysis

Table 2.1: Literature summary

Sr No.	Author	Area of research	Contributions and applications of research
1	Arasu, A V et al.(2007)	Theoretical analysis of PTC with hot water generation	The modeling of a parabolic trough collector with hot water generation system with a well mixed type storage tank using a computer simulation program PV power systems generate electricity via the direct conversion of sunlight into electrical energy and can serve as an environment
2	Khlaichom, P et al.(2007)	Optimization of Solar Tracking System based on genetic algorithm	The current trend in solar concentrator tracking system is to use an open-loop local controller that computes the direction of the solar vector based on geographical location and time. But it is not enough accuracy because it has error from computing the sun's position, mechanical, controller systems and installation
3	Lorenzo, E et al.(2002)	Design of Tracking Photovoltaic Systems with a Single Vertical	This paper examines the theoretical aspects associated with the design of azimuth type of tracking, taking

		Axis	into account shadowing between different trackers and back-tracking features. The practical design of this trackers installed at the 1.4 MW Tudela PV plant is accessible
4	Helwa, N H et al.(2007)	Maximum Collectable Solar Energy by Different Solar Tracking Systems	A practical study was carried out on different solar tracking systems. The layout of these systems are facing south and tilted 40 ⁰ a vertical-axis tracker a 6 ⁰ tilted-axis tracker, and a double-axis tracker. All the trackers are microprocessor based and have photovoltaic arrays for electric energy production
5	Chicco, G et al.(2008)	Performance of Grid-Connected Photo voltaic Systems in Fixed and Sun-Tracking Configurations	The focus of the paper is twofold. The first one part concerns the assessment of the energy production and of the operational characteristics of multiple photovoltaic systems in Sun-tracking configurations by comparing their performance to the one of the corresponding fixed PV systems. The second part consisting the harmonic characteristics of the integration of several converters in PV plants of various size
6	Stern, M et al.(2010)	Development of a low cost integrated 20 Kw AC solar tracking sub-array	PV power systems generate electricity via the direct conversion of sunlight into electrical energy and can serve as an environmentally

			benign and domestically secure source of electricity for utility grid connected peak or intermediate load applications
7	Naidoo, P et al.(2002)	Intelligent control & tracking of a parabolic trough solar collector	The aim of this research paper is to test the solar-to-thermal energy efficiency of a tracking line-focus parabolic trough solar collector
8	Duarte, F et al.(2010)	Two axis solar tracker based on solar maps, controlled by a low-power Micro controller	This work studies the solution of two axis solar tracking system based on solar maps, which can forecast the exact apparent position of the Sun, by the latitude's location, thereby neglecting the need to use sensors or guidance systems
9	Lee, C Y et al.(2009)	Thermal analysis of PTSC	The monthly average collector output at Darwin is almost steady during the year. The collector thermal loss when using synthetic oil as the working fluid was found to be higher than in the DSG collector
10	Alkilani, M M et al.(2009)	Performance of PTSC	Effects of glass cover, vacuum, pressure drop, incident angle, flow rate, and wind speed are calculated
11	Brogren, M et al.(2007)	Properties of aluminum-polymer laminated steel reflector	The optical properties, durability, and reflector performance is calculated and most importantly the cost-effectiveness of the reflector
12	Bartl, J et al.	Effect of emissivity on	Worked on the emissivity of Alloys

	(2010)	the Surface temperature of the collector	of aluminium with magnesium and silicon and found that they are tough, have high electrical conductivity, high emissivity, but are still lower in comparison to other metals
13	Gee, R et al.(2007)	Reflector specularity	Studied the Impact of reflector specularity on the optical performance of parabolic trough solar collectors. It is observed that the Metalized polymer reflectors are less specular than glass mirrors
14	Kalogirou, S et al.(2007)	Performance prediction by simulation	Experimental verification of the PTC model and analysis of the experimental results for hot water production.
15	Scrivani, A et al.(2009)	Parabolic Trough use in different applications	Waste water treatment, solar distillation, refrigeration without electrical power

2.5 Gap Finding

The work in the field of solar tracking system has been reported by various researcher for increasing the heating temperature for a particular period and increasing the efficiency of solar collector. But no work has been reported for the development of automatic solar tracking of Design and analysis of automatic solar tracking system for parabolic trough collector for hot water generation and improving its efficiency.

Objectives

- To design and manufacturing of automatic solar tracking system for parabolic trough collector for hot water generation.
- To study the effect of solar tracking on the temperature gain and efficiency of the automatic solar tracking system for parabolic trough collector for hot water generation.

METHODOLOGY OF THE WORK

3.1 Introduction

The present study aims at Design, Fabrication, Characterization, and Experimental analysis of Automatic tracking system of prototype parabolic trough concentrator using Glass Mirror as the reflective material. In the past work Glass Mirror has a high reflectivity as compare to other materials like Stainless Steel, Aluminium Foil[Sanjay 2012]. So Glass Mirror is used as the reflective material in the purposed work. Different observation has been carried out to obtain best suitable result of Parabolic Trough Collector in terms of its improved efficiency. Generally the efficiency of a PTC is given by

$$\text{————— [Garg, H P & Prakash, J 1997]}$$

(4.1)

Where F_R = Heat removal factor

η_o = Optical efficiency

U_L = Heat loss coefficient

CR = Concentration ratio

It can be realized that the efficiency of a PTC depends on the optical efficiency (η_o) of the reflective material. Glass mirror has a high optical efficiency as compare to other material In the present work glass mirror is used for improving the optical efficiency of the concentrator. In equation (4.1), F_R , U_C and η_o can be identified as the three major design parameters which can be used to construct a three-parameter collector model for the preliminary design of PTC.

In present study we are using Copper tube (bare and glazed) as an absorber tube with Glass Mirror as an reflective material and different testing are carried out. By these observations, we analyze the results obtained by experimental data and compared the Manual, Automatic and Fixed Position sun tracking system in terms of their enhanced efficiency for present prototype PTC. Best tracking system is that which gives the high efficiency of prototype parabolic trough concentrator and is used for further practical application like air heating, domestic water heating, steam generation etc.

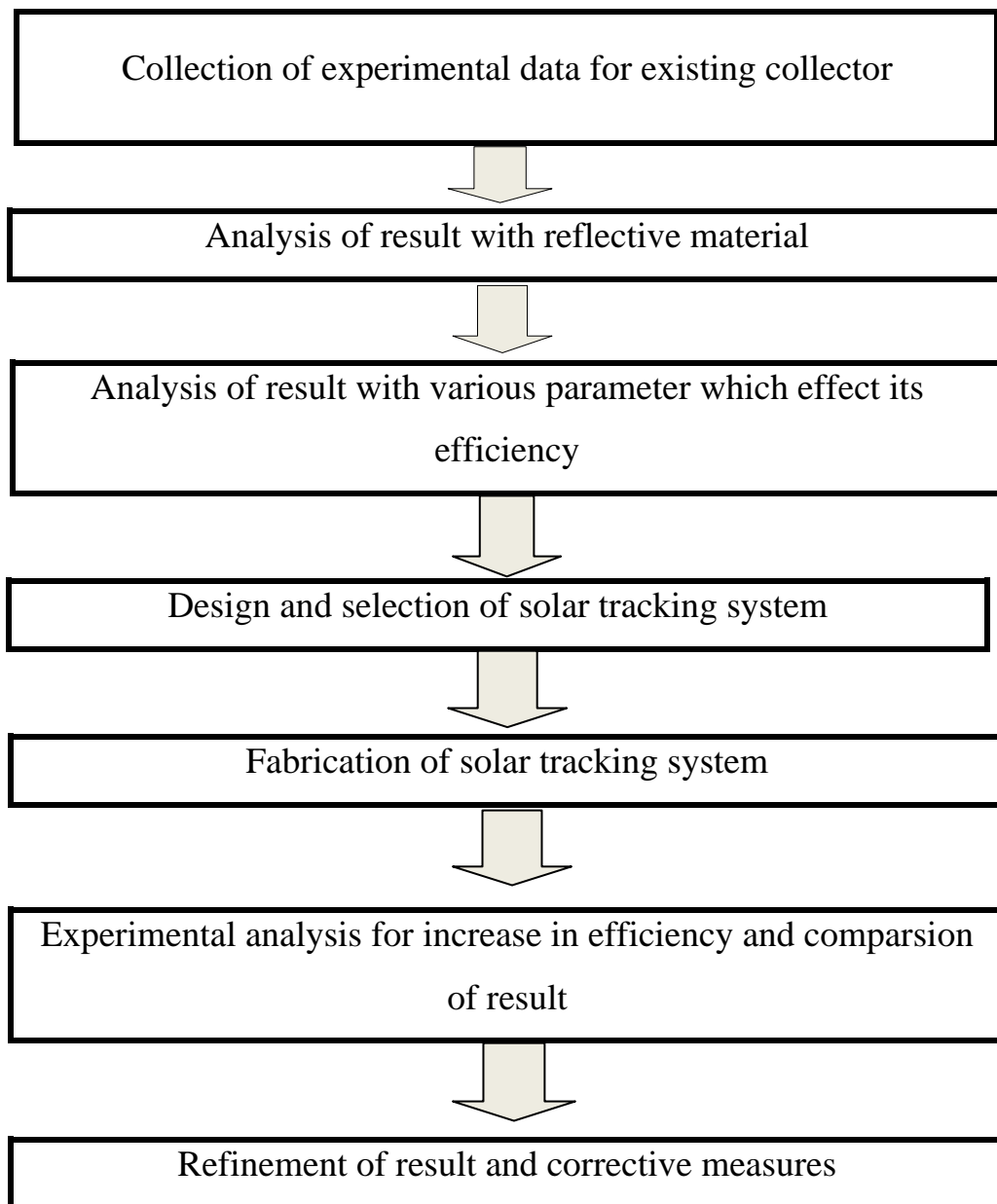


Figure 3.1

CHAPTER-4

DESIGN AND FEBRICATION

4.1 Design of prototype parabolic trough concentrator

Parabolic trough collectors are structurally simpler than other types of collectors although some form of tracking (we have used automatic tracking) must be employed and the parabolic surface must be precise, to ensure efficiency. In order to be cost effective the parabola of the PTC must be produced in such a way so as to be low priced and perfect and in the construction of parabolic trough, we have no need of so much labour, its construction are simple and or a mass production manufacturing process.

4.1.1 Design Parameters

The design parameter of a parabolic trough collector can be classified as geometric and functional. The geometric parameters of a PTC consist of aperture width and length, focal length, rim angle, diameter of the receiver, and diameter of the glass envelope.

The functional parameters of a PTC consist of its optical efficiency, instantaneous efficiency and all day thermal efficiency and receiver thermal losses. These parameters are largely affected by the absorptivity of the absorber. The errors are caused due to the defects in reflective material, support structure, location of the PTC.

4.1.2. Design of prototype PTC using PARABOLA CALCULATOR 2.0

Initial specification for design of Parabolic Trough Concentrator is obtained by considering parabolic equation: $X^2 = 4aY$

Where

Y=distance along vertical axis.

a=focal length.

X=distance along horizontal axis.

A parabola is obtained by using a parabola equation. By putting different Y values in the equation, it gives different X values. In this way, different X,Y points are obtained and finally get a parabolic shape at different x, y points. Another method for drawing the parabola is the software named as “PARABOLA CALCULATOR 2.0” Which is easily available on the internet. PARABOLA CALCULATOR 2.0 is shown below and data obtained is given in Table 4.1 and 4.2. All dimensions are in feet (ft) as unit.

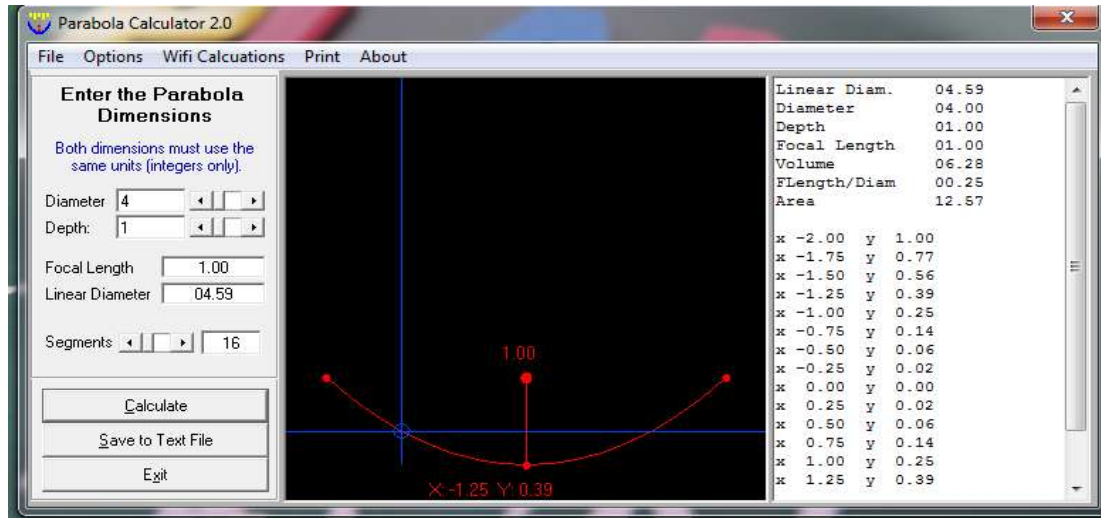


Figure 4.1 PARABOLA CALCULATOR 2.0

Table 4.1: Design parameters for prototype parabolic trough collector

PARAMERER	DESIGN VALUE
Linear Diameter	04.59 ft
Diameter	04.00 ft
Depth	01.00 ft
Focal Length	01.00 ft
Volume	06.28 ft

Flength/Diam.	0.25 ft
Area	12.57 ft

Table 4.2: X and Y values for prototype parabolic trough collector

X-HORIZONTAL AXIS	Y-VERTICAL AXIS
-2.00	1.00
-1.75	0.77
-1.50	0.56
-1.25	0.39
-1.00	0.25
-0.75	0.14
-0.50	0.06
-0.25	0.02
0.00	0.00
0.25	0.02
0.50	0.06
0.75	0.14
1.00	0.25
1.25	0.39
1.50	0.56
1.75	0.77
2.00	1.00

4.2 Fabrication of Prototype Parabolic Trough Concentrator

In present thesis work consideration of cost is essential because we have considered cost analysis for best design and feasibility of proposed parabolic trough concentrator. Since trough should be capable of withstanding different loads like wind load, stress loads etc,

so it should be rigid body in design. In present work, mild steel is used as material to form a parabolic shape in prototype.

In the present work, a mild steel sheet is bent into parabola with a focus at 0.305m. The sheet has linear diameter is 4.57 ft. and width of the sheet is 3 ft. 'Parabolic calculator 2.0' is very helpful for drawing the parabola. 'Parabolic calculator 2.0' requires the diameter, depth, focal length, linear diameter. By filling these required columns, a parabolic structure is generated. An automatic tracking system is fabricated at the axis of the absorber tube. The receivers are a cylindrical copper pipe painted black with appropriate black paint. The paint coat is kept as thin as possible so that there is minimum resistance of flow of heat through the coat through the pipe and to the heat transfer fluid. The collector is covered with a 2 mm thick glass cover.

To have a firm foundation we prepared a mild steel base as shown in following photos of prototype PTC. Different Components of Prototype PTC are shown in given pictures below:

4.2.1 Parabolic Trough reflective material

In the past work it may be found that glass mirror has a high reflectivity as compare to stainless steel and aluminum foil[Sanjay 2012]. So in the present work glass mirror is used as the reflective material.

4.2.2 Glass Mirror as concentrator



Figure 4.2 PTC with Glass Mirror

Glass mirrors are pasted on the parabolic sheet with the help of silicon and double tape. Glass mirrors are 25 in number with dimensions (5mm x 3ft). These mirror strips does not affect the parabolic curve shape. The mirror stripes are used because they have a very high reflectivity of 93%. The reflector made up of mirror stripes pasted on a metal sheet is shown in figure 4.2.

4.2.3 Absorber Tube

A black painted copper tube is used as an absorber tube. Copper tube is covered by a glass tube to reduce the conductive, convective and radiation losses. A copper tube has 4ft length and with inside and outside diameter of 27 & 28 mm is used and glass tube has length 3 ft with inside and outside diameter is 64 & 66 mm.



A black painted copper tube covered by a glass tube

Figure 4.3 Absorber tube

4.2.4 Storage Tank

A Storage Tank is a 15ltr capacity filled with water, and it is made up of steel. Water is circulated through the storage tank from the copper tube with the help of a pump of power 24W. When water is comes inside the copper tube from the storage tank. It takes heat, and after that it supplies heat to the water inside the storage tank. The inlet and

outlet of the copper tube is from the storage tank. The storage tank is insulated with the help of glass wool, and it is placed inside the box. Figure 4.4 shows the picture of storage tank placed inside the card-board box.



Figure 4.4 Storage Tank insulated with Glass wool and packed in Box

4.2.5 Insulations

Glass wool insulation is on the storage tank which is inside the card-board box. Glass wool insulation reduces the heat loss from the storage tank. Soflon insulation is covered on the pipes. Which minimize the heat loss, when water is flowing through the pipes from the inlet to the outlet via storage tank. These both insulation are easily available in the air conditioner and refrigerator spare part shop. Figure 4.5 shows the picture of the insulations on the storage tank and the pipes.

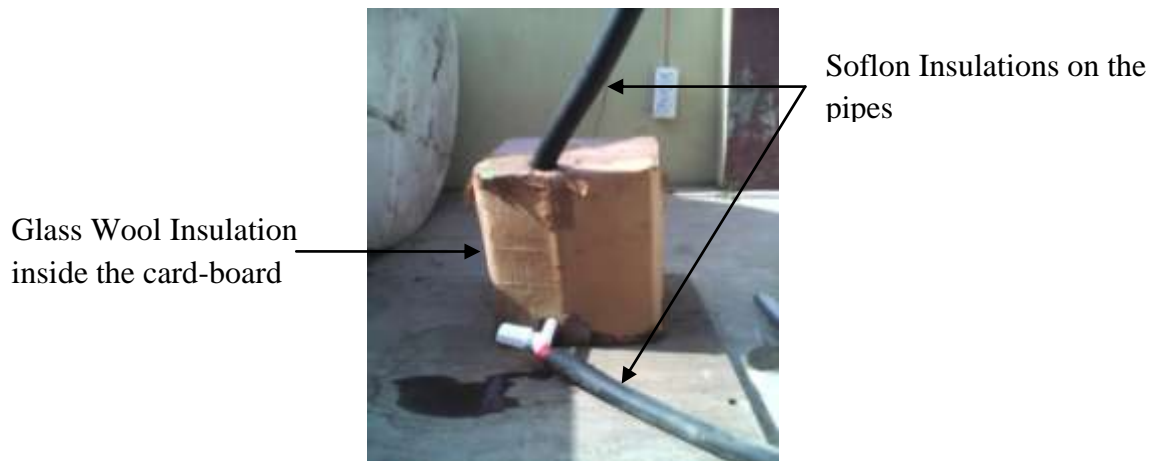


Figure 4.5 Insulation on the Storage tank and the Pipes

4.2.6 Support Structure

The support structure for the parabolic trough solar collector is made of mild steel. The selection of mild steel as a material for the support structure because it fulfill the drawback of wood which is used in the past work [Sanjay 2012]. The mild steel is cheap, easy to maintain, and great rigidity, hardness and more flexible. All the parts of the base are joined by welding. The support structure which is made up of mild steel is green painted. The support structure is made in such a way that it can hold all type of load like wind loads, stress loads etc. It is also designed so that it could not affect the shape of the parabola and also to minimize the alignment error. The tracking system was joined on the support structure.



Figure 4.6 Support Structure

4.3 Manual Tracking System

In the manual tracking system the parabolic trough is oriented in an east to west direction, because sun is also moved from east to west direction. In this the parabola is rotated by 10 degrees after every 1 hour. In this an angular chart is made on the card-board. This card-board is fixed to that edge which is in line with the focus of the parabola. The

parabola is rotated with the help of a DC motor and a battery system. When the shadow of the copper tube is at the centre of the parabola means it is on the focusing medium and all mirror reflection fall on the copper tube, after that check the angle on the angular chart, when the parabola is on the focusing medium.



Figure 4.7 Manual Tracking System

4.4 Automatic Tracking Mechanism

In the automatic tracking mechanism, we used two type of tracking system

- 1) Vertical tracking system
- 2) Horizontal tracking system

4.4.1 Automatic Vertical Tracking Mechanism

For getting the maximum solar intensity, a tracking system is used which track the sun in all direction is known as tracking mechanism. Tracking system is either manually or automatic. In present work automatic sun tracking system is used so that parabolic concentrator automatically tracks the sun in all direction. In this DC motor (1500 rpm), Sprocket type gear, and lead screw is used. The parabolic concentrator is hold by a rod which helps the parabola to move easily in east-west directions. In the automation of the parabola, one end of the lead screw is attached at the one side of the parabola, and the other end of the lead screw is fixed with the motor shaft. The motor is enclosed inside the metal box and a thrust bearing is fixed at the top of the metal box inside the motor shaft

to reduce the whole parabola weight on the motor. The base of the motor is fixed with the U-clamp joint, this U-clamp joint is helpful for the motor to take any up and down direction when the parabola is in the working condition. When the lead screw is tight with the help of motor the parabola take the downward direction and when the lead screw is loose, the parabola takes the upward direction. In this way it track the up and down movement of the sun.

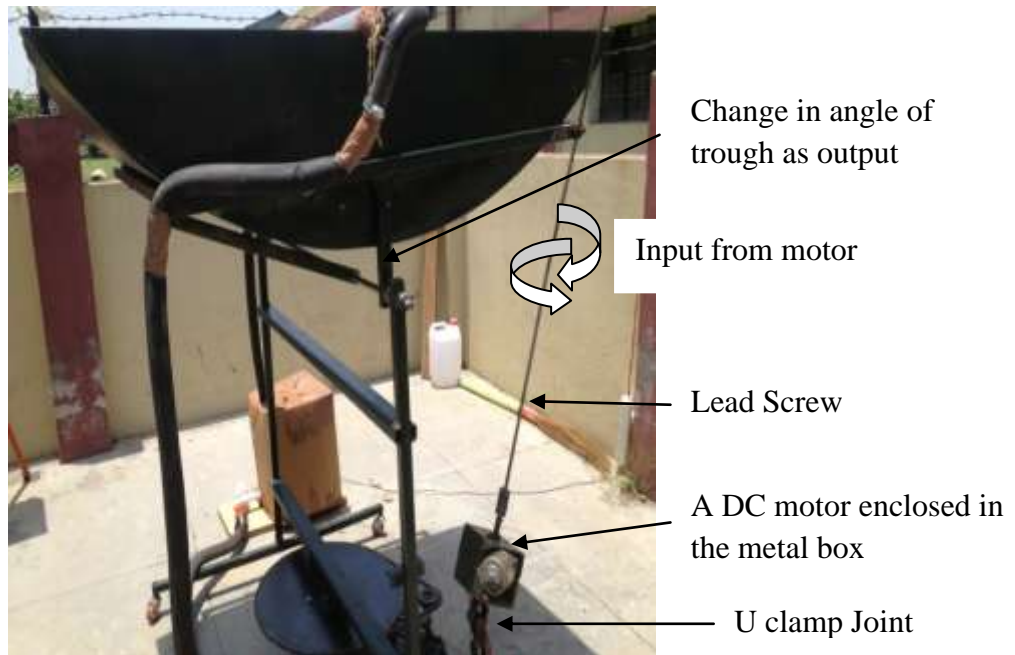


Figure 4.8 Automatic Vertical Tracking Mechanism

4.4.2 Automatic Horizontal Tracking Mechanism

In the horizontal tracking system whole body is rotated in the horizontal direction around a shaft which is fixed to the ground with the help of the base plate. The whole structure is rotated 360° around the shaft, and the four wheels are mounted to the base of the structure. These four wheels drives the whole structure around a centre shaft when the motor is in the working condition. In this a shaft of 42 mm diameter and 185 mm length is used. By machining a UC bearing of size 35 mm is fitted inside the shaft. The upper edge of the UC bearing is fixed to the sprocket, which has 1.5 ft diameter and 110 teeth are cut. This big sprocket is fixed to the frame with the help of nut and bolt. A DC Motor (1500 rpm) is fixed to the mechanism which is welded at the base plate. A small sprocket

is fitted to the motor shaft with the help of L-Key. A chain is passes around the both sprockets to drive the whole frame with the help of DC Motor.



Figure 4.9 Automatic Horizontal Tracking Mechanism

4.5 Automatic Tracking System

4.5.1 Components of Automatic Tracking System

There are many components which are used in the automatic circuit. These components are explained briefly in below.

4.5.1.1 Sensor Casing

A circular pipe of length 12 inch and diameter 2 inch is used. The whole electronics circuit is fitted inside the circular pipe. The circular pipe is used because it completely tracks the sun as a small radius of pipe. The light is focused very easily in the circular pipe.



Figure 4.10 Circular Pipe

4.5.1.2 Lenses

Two convex lenses which have 2 inch circular diameter and 6 inch focal length are used. When solar light passes through the slits, it falls on the convex lenses. The convex lenses focus the light on the LDR.

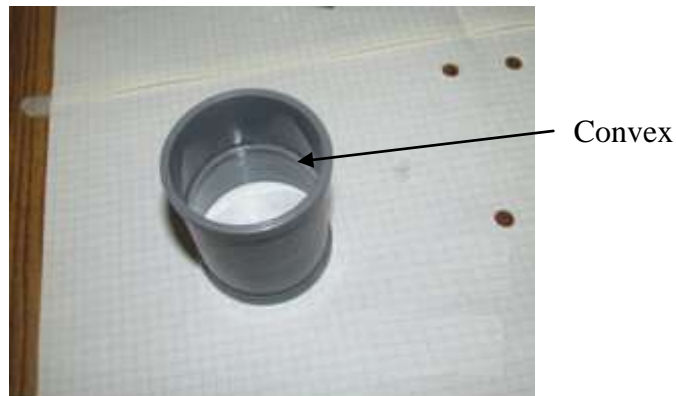


Figure 4.11 Convex Lens

4.5.1.3 Light Dependent Resistors (LDR)

A Light dependent resistor is a light sensing device which is used in the electronics circuit to detect basic changes in light level. It is also called as photo resistor.

When light falls on the light dependent resistor, the resistance value changes depending on the amount of light falling on it, and the whole circuit is in the working condition,

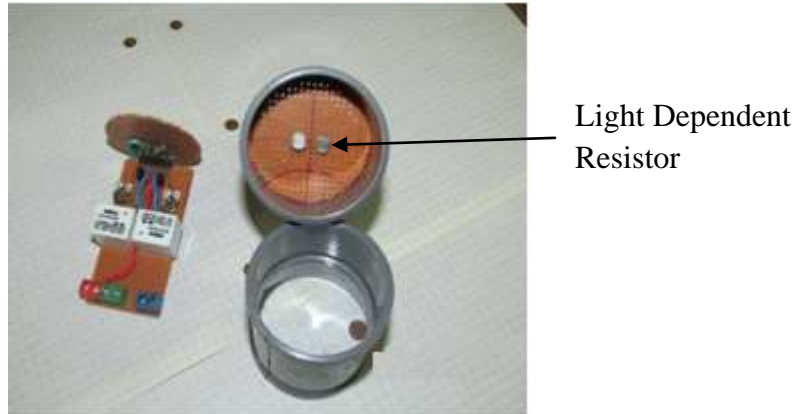


Figure 4.12 Light Dependent Resistors (LDR)

4.5.1.4 Transistor 2N2222

The Transistor 2N2222 is one of good and commonly used transistor, which has numerous switching applications in electronics circuit. The main advantage of this transistor is that it manages a high magnitude of currents as compare to other small signal type of transistor. Its capacity to switch 800 mA of current through it. It will be activated when sun light falls on the LDR.

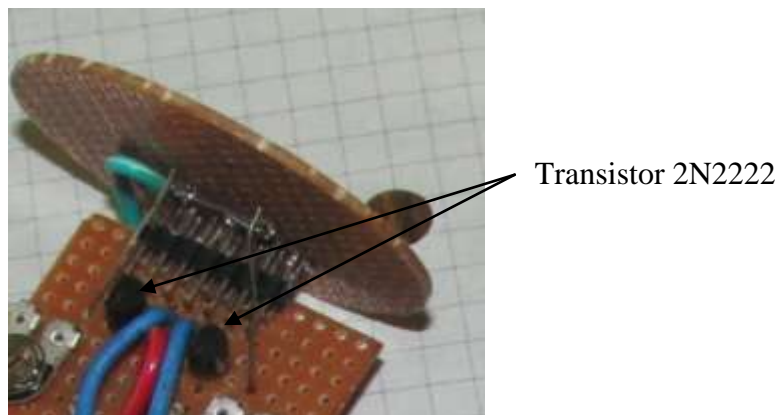


Figure 4.13 Transistor 2N2222

4.5.1.5 Variable Resistance

It is used to change the resistance from 0 to 100K. The value of voltage can be adjusted with the help of variable resistance as per requirement.

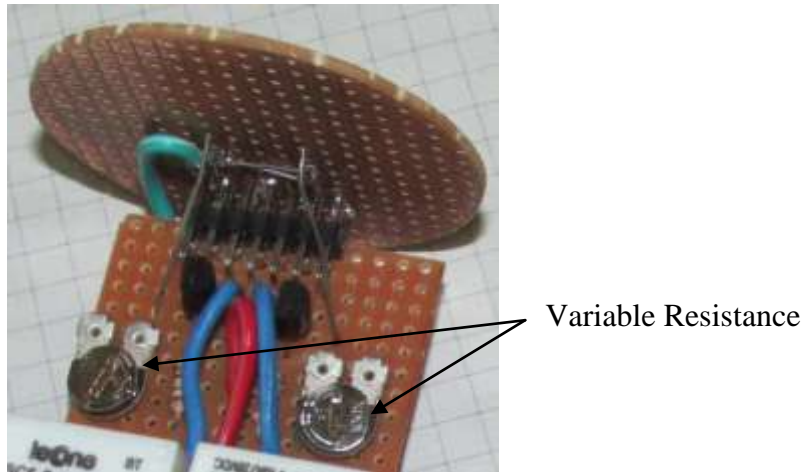


Figure 4.14 Variable Resistance

4.5.1.6 Relay

Relay is a electric switch used to change the direction of the current. When relay switch is ON, the current passes through it and the motor moves in one direction and when relay switch is OFF, it restrict to flow of the current, and the motor is in the stop position.

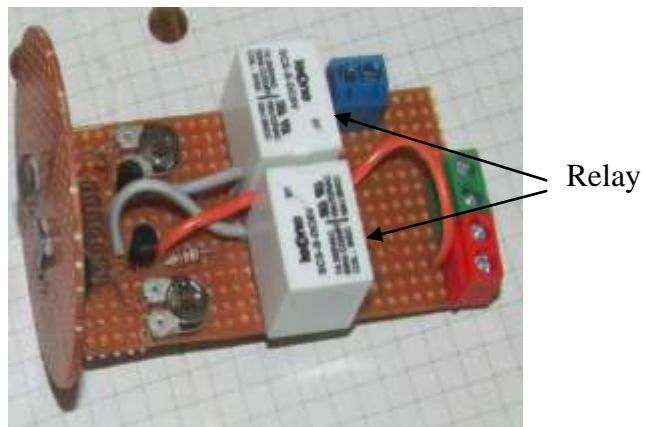


Figure 4.15 Relay

4.5.2 Circuit diagram of Automatic Tracking System

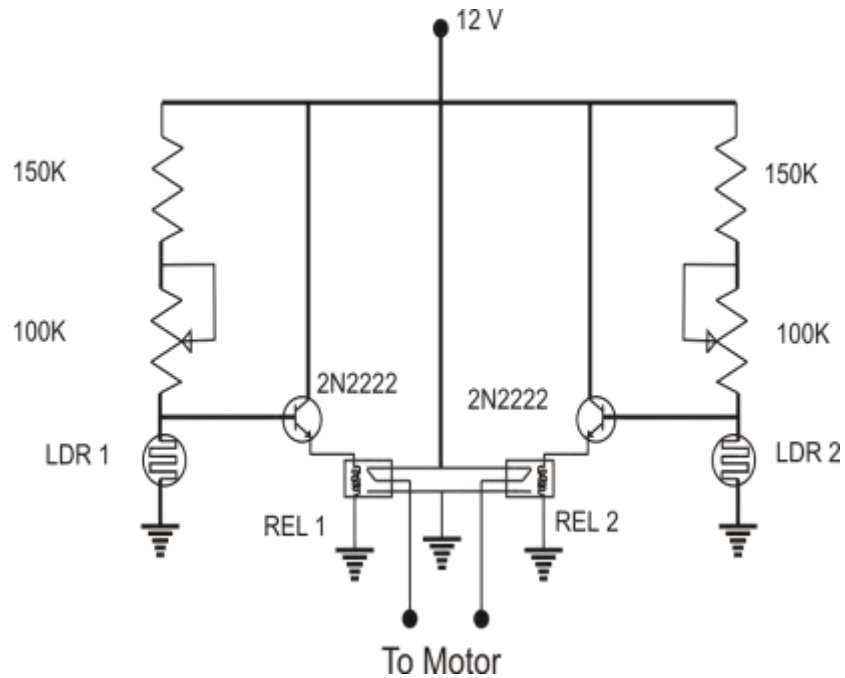


Figure 4.16 Circuit diagram

When light falls on the light dependent resistor (LDR) the resistance value changes depending on the amount of light falling on it.

When the resistance value approaches '0' the transistor 2N2222 is activated and it switches ON the relay.

Depending on which light dependent resistor (LDR) is switches ON, the corresponding relay is switched ON.

Due to the connection of the relay the voltage to the motor gets reversed and the motor will turn in either direction.

4.5.3 Assembled view of the Electronics components



Figure 4.17 Assembly of all parts

All the components of the electronics circuit are assembled as shown in the figure 4.17. The electronics component is assembled on the printed circuit board (PCB). In the assembly, lens are fitted at the centre of the pipe, and the electronics circuit are fitted in such a way that when light passes through the slit and strike on the lens, the focus of the lens is on the light dependent resistor (LDR). A small gap is provided in the pipe to check the focus of the lens, and after the assembly of all parts pipes are fitted with each other.

4.5.4 Working principle of Automatic Parabolic Trough Concentrator



Figure 4.18 Automatic Parabolic Trough Concentrator

The electronics circuits are fitted with the parabolic trough as shown in the Figure 4.18. Two electronics circuit are used which is fitted in the circular pipe. One circuit is used to control the base movement of the concentrator, and other is used to control the movement of the parabola. The slit are cut in such a way that the light after passing into the lens falling on the LDR. In the control of the horizontal movement, the slit are cut vertically and in the control of the vertical movement the slit are cut horizontally. When light passes through the vertical slit, it strikes on the lens and focus of the lens is in between the two LDR. At that stage motor is in the stop condition, and parabola is in the focusing medium. When sun changes his direction, the focusing of the light in between the two LDR is disturbed, and the focusing light is going in the direction of any one LDR. The motor starts working when the focusing light is any one of the LDR, and it takes the sunlight in other direction that means in between the two LDR. So in this way both movement of the parabolic trough concentrators are controlled.

4.6 Temperature and Solar Intensity Measuring Instruments

There are some instruments which are used to measure the temperature of working fluid and the solar intensity. These are:

4.6.1 Lux Meter

A lux meter is used to measure the solar radiation coming from the sun. In the lux meter it has a small display which shows the amount of solar radiation, and one sensing part, which sense the solar radiation and shows on the display. A lux meter which is used in the experiment is shown in the figure 4.10.



Figure 4.19 Lux Meter

4.5.2 Thermometer



Figure 4.20 Thermometer

A Thermometer is used to measure the temperature of hot water inside the storage tank. The range of thermometer is -10 to 110 . A red line tells the temperature of water. When the thermometer is put inside the water, the red line raises and stop to that scale point which the water attain the temperature. The picture of thermometer is shown in the figure 4.11.

Table 4.3: Parabolic trough Collector specification

ITEMS	VALUE
Collector Length	1.20 m

Collector breath	0.91 m
Aperture area	1.098
Rim angle	90°
Receiver inside diameter	0.027 m
Glass envelope inside diameter	0.064 m
Receiver outside diameter	0.028 m
Glass envelope outside diameter	0.066 m
Concentration ratio	11.30
Focal distance	0.30 m
Water flow rate	0.083 kg/s
Storage tank capacity	15 lt
Tank material	Stainless steel
Tank insulation material	Glass wool
Water pump	25 W
Insulation on the pipes	Soflon

CHAPTER-5

EXPERIMENTAL ANALYSIS

5.1 General

The performance of parabolic trough collector depends on the system efficiency, instantaneous efficiency and overall thermal efficiency. These efficiencies are obtained by different collections of the storage tank water temperature (), ambient temperature () and collector water outlet temperature (). The values of different temperature are recorded by a thermometer as shown in the figure 5.1.

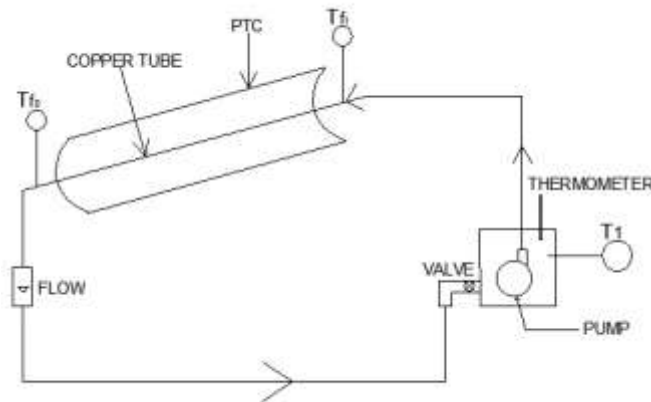


Fig. 5.1 Line diagram of PTC with thermometer

The useful energy collected per unit time in a solar collector system employing solar concentrators may be written as:

$$\text{—————} \quad [\text{Garg, H P \& Prakash, J 1997}] \quad (5.1)$$

It may also be written as

$$[\text{Garg, H P \& Prakash, J 1997}]$$

(5.2)

The heat removal factor may be written as

$$\text{—————} \quad [\text{Garg, H P \& Prakash, J 1997}]$$

(5.3)

By subtracting equation (1) to (3),

$$(5.4)$$

By solving it gives

$$(5.5)$$

5.2 Design analysis

The design analysis of parabolic trough collector depends on the instantaneous efficiency. And the instantaneous efficiency is calculated from an energy balance on the receiver tube. The instantaneous efficiency is defined as the rate at which useful energy is delivered to the working fluid per unit aperture area (divided by the beam solar flux (at the collector aperture plane.

$$= - \text{—————} \text{ [Garg, H P \& Prakash, J 1997] } \quad (5.6)$$

In equation (5.6) , and are the three major design parameters which can be used to construct a three-parameter design model for the design of parabolic trough collector.

The optical analysis of the collector can be linked from the thermal analysis, if we assumed that the optical properties of the materials are temperature independent. Hence the optical efficiency can be made and analyzed independently without knowledge of the thermal design and vice versa.

5.3 Optical analysis

The optical efficiency can be written as

$$\text{[Garg, H P \& Prakash, J 1997]} \quad (5.7)$$

Where

= average specular reflectance of the reflective surface

= effective transmittance-absorptance factor

= angle of the incidence of the sun's rays on the collector aperture measured from the normal to the collector

= instantaneous intercept factor which may defined as the fraction of the rays incident on the aperture that reach the receiver for a given incidence ()

In the equation (5.7) the optical efficiency varies with the incoming radiation and the angle of incidence between the aperture surfaces normal. The optical efficiency decreases with increasing incidence angle and intercept factor also decreases with incidence angle. Many factors besides play a great role for decreasing the optical efficiency. These factors include the incident angular dependence of glazing transmittance and absorber absorptance.

5.4 Thermal analysis

The primary function of the absorber tube for a parabolic trough collector is to absorb the energy and then transfer this energy to the fluid which passes among the tube. In this process, the absorber will be heated when its temperature is higher than that of the atmosphere temperature. For example, depending on the temperature requirements of the application, operating temperature as high as 300 can be attained at the absorbing surface of the receiver during operation. So there is a temperature difference between the absorbing surface and the surrounding will result some of the collected energy is transferred to the surroundings. The information of the heat loss from the receiver is important for find out the performance of parabolic trough collector and hence designing

Heat is transferred in the following steps:

- (1) First heat is transfer from the glass mirror to the absorber tube.
- (2) After that heat is transfer from the absorber tube to the working fluid.
- (3) Heat exchange between the glass jacket and the surrounding.

5.5 Calculation for performance analysis in Automatic Tracking System

A prototype parabolic trough collector is placed in Thapar University Patiala. Tracking mode is such that it can track in all directions (Automatic Tracking) for hot water generation. The concentrator has aperture area of 1.035 m², and length is 1.20 m, and the absorber tube has inner diameter is 27 mm, and outer diameter is 28 mm. and the glass tube which is covered on the copper tube has inner diameter is 64 mm and outer diameter is 66 mm. The other design parameter values is given in table 5.1.

TABLE 5.1 Values of other design parameter of concentrators

Specular reflectivity of the concentrated surface	0.93
Absorptivity of the absorber tube()	0.90
Glass cover transmittivity for solar radiation	0.88
Intercept factor()	0.95
Date	24 June, 2013
Time	12-01pm
	906
Ambient temperature	35
Mass flow rate of water	0.083
Outlet temperature	85

(1) The absorbed flux(S) is given by

$$S = \quad \quad \quad (5.8)$$

$$S=878.[.95*.93*.90*.88]$$

$$614.36\text{W/m}^2$$

(2) Convective heat transfer coefficient

Properties will be taken at a mean fluid temperature of 64.5 .

$$\text{Thus } \rho = 1000$$

$$c_p = 4.2\text{KJ/kg}$$

$$\nu = 0.439$$

$$k = 0.654\text{W/m-K}$$

$$\text{Average Velocity } V = \frac{S}{\rho c_p} = \frac{614.36}{1000 \times 4.2} = 0.026\text{m/s}$$

$$\text{Reynolds number } = \frac{V D}{\nu} = \frac{0.026 \times 0.05}{0.439} = 3790.43$$

$$\text{Prandtl number } = \frac{c_p \mu}{k} = \frac{4200 \times 0.000439}{0.654} = 2.81$$

$$\text{Nusselt number } = 0.023$$

$$= 0.023 \quad (\text{where } n=0.4 \text{ for heating})$$

$$= 25.36$$

$$\text{Therefore } h = \frac{k}{D} \times 25.36$$

$$= 24.60 \times 0.05 = 259.14\text{W/m}^2\text{K}$$

(3) Collector heat removal factor and overall loss coefficient

Assume $h = 13.28 \text{ W/m}^2\text{K}$, so the collection efficiency factor

$$F' = \frac{h A_c}{h A_c + U_L A_r}$$

$$= \frac{13.28 \times 10}{13.28 \times 10 + 10 \times 10}$$

$$= 0.94$$

So $\frac{h A_c}{U_L A_r} = \frac{13.28 \times 10}{10 \times 10} = 105.5$

Therefore heat removal factor

$$F_R = \frac{1}{1 + \frac{U_L A_r}{h A_c}}$$

$$= \frac{1}{1 + \frac{10 \times 10}{13.28 \times 10}}$$

$$= 105.10$$

(4) Concentration ratio

$$C = \frac{A_c}{A_r} = \frac{10}{1.04}$$

(

$$= \frac{10}{1.04}$$

$$= 9.66$$

(5) Optical efficiency

$$= \frac{\text{Useful heat gain rate}}{\text{Incident solar radiation}} \quad \text{where}$$

$$= \frac{113.75 \text{ W}}{160 \text{ W/m}^2 \times 0.706}$$

$$= 0.93$$

$$= 0.706 \text{ or } 70.6\%$$

(6) The useful heat gain rate

$$= 113.75 \text{ W}$$

(7) Instantaneous efficiency

$$\frac{\text{Useful heat gain rate}}{\text{Incident solar radiation}} \quad (r_b = 1) \quad (5.9)$$

$$= 7.27\%$$

(8) Thermal Efficiency of system(per hour)

Taking,

Mass of water (

Specific heat of water (4.2KJ/kg-K

$$\text{Efficiency ()} = \frac{\text{Useful heat gain rate}}{\text{Incident solar radiation}} \quad (5.10)$$

$$= \frac{\text{Useful heat gain rate}}{\text{Incident solar radiation}}$$

$$= 12.51\%$$

(9) Overall thermal efficiency (average)

Taking,

Mass of water (

Specific heat of water (4.2KJ/kg-K

Time duration (t)=4 hours(9am-12pm)

Aperture area ()=1.387m²

$$\text{Efficiency()} = \text{_____} \quad (5.11)$$

$$= \text{_____}$$

$$= 27.45\%$$

5.6 Experimental study of Glass Mirror with bare copper tube by using Manual tracking Mechanism

Reflective material = Glass Mirror

Reflectivity of Glass = 0.93

Absorber Tube = Copper Tube

Diameter of Copper Tube = 28 mm
 Area = 1.1163 m²

Table 5.2: Temperature variation of Glass Mirror by taking Intensity (Bare Tube)

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C	ANGLE (degree)
09-10	520	47	34	140-130
10-11	728	56.5	47	130-120
11-12	918	63	56.5	120-110
12-01	896	68.5	63	110-100
01-02	775	68	68.5	100-90
02-03	650	67	68	90-80
03-04	512	65.5	67	80-70
04-05	436	62.5	65.5	60-50
05-06	320	59.0	62.5	40-30

The above reading has been taken on 18 May, 2013, day is normal at morning, noon and evening.

The above table shows the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is recirculated from the storage tank and it passes through the copper tube and acquires the heat, and then this heat is transferred to the storage tank and thus the temperature of the storage tank rises. At that day 18 May, the ambient temp of water is 34 at 9.00am and it reaches his maximum level of 68.5 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period. During this process the flow rate of water through the collector is 0.083 kgps. At any moment, the collector water temperature has been greater than that of storage tank water temperature.

Table 5.3: Performance data in glass mirror concentrator (Bare tube) by using Manual Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/ ()	System efficiency	Overall thermal efficiency
227.5	22.10	40.69	
166.25	12.27	20.45	
113.75	6.95	11.10	
96.25	5.34	9.62	17.66

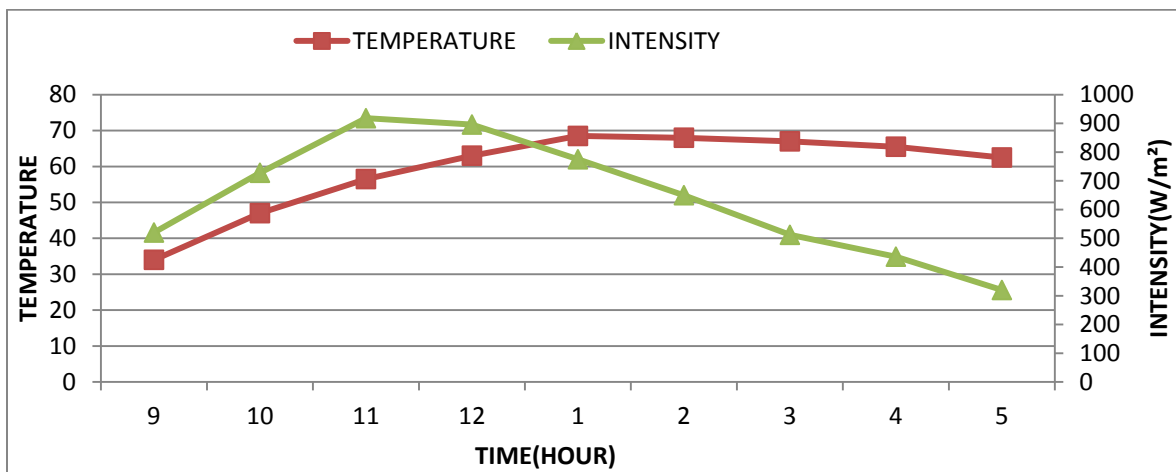


Figure 5.2 Variation of collector water temperature outlet temperature, , and beam radiation I with time

Figure 5.2 shows the variation of collector water outlet temperature, , and beam radiation I with time on one day, viz. 18 May, 2013. The collector water outlet temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

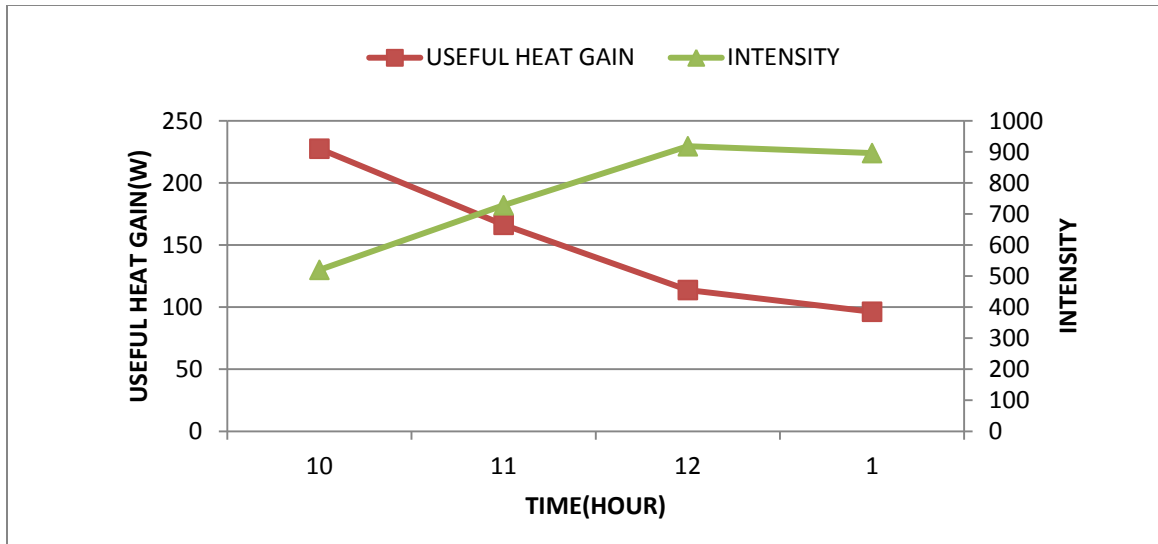


Figure 5.3 Variation of useful heat gain, , and beam radiation, I, with time

The variation of useful heat gain, , and beam radiation, I, with time is shown in the figure 5.3. It is seen that a smooth variation of beam radiation, and attain maximum temperature (918) around noon. The useful heat gain first increases from morning, and reach a peak value, and after then start decreases. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

Figure 5.4 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency decreases with time and solar intensity increases. The hourly system efficiency (thermal efficiency) decreases per hour as useful heat gain decreases continuously.

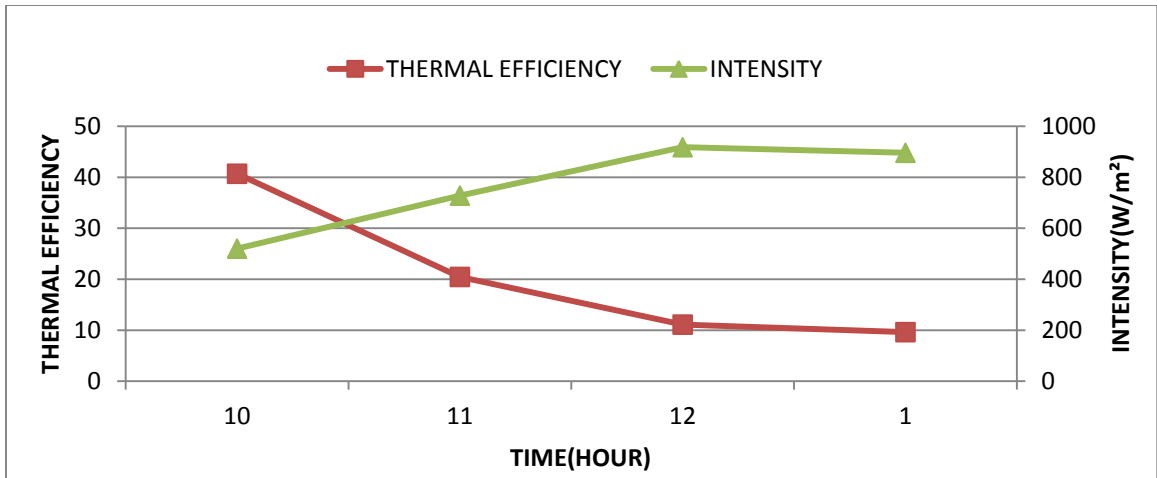


Figure 5.4 Variation of Thermal Efficiency and intensity with time

5.7 Experimental study of Glass Mirror with Glazed copper tube by using Manual tracking system

Reflective material	=	Glass Mirror
Reflectivity of Glass	=	0.93
Absorber Tube	=	Copper Tube
Diameter of Copper Tube	=	28 mm
Glazing material	=	Glass tube
Glass tube diameter	=	66mm
Area	=	1.035 m ²

Table 5.4: Temperature variation of Glass Mirror by taking Intensity (Glazed Tube)

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C	ANGLE (degree)
09-10	523	48.5	34	140-130
10-11	740	59.5	48.5	130-120
11-12	925	69	59.5	120-110
12-01	890	75	69	110-100
01-02	780	74.5	75	100-90
02-03	675	73	74.5	90-80
03-04	525	71.5	73	80-70
04-05	410	69	71.5	60-50
05-06	290	66	69	40-30

The above reading has been taken on 19 May, 2013, day is normal at morning, noon and evening.

Glazed means a glass tube is fitted around the copper tube to prevent the conduction convection and radiation losses. The above table shows the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is recirculated from the storage tank and it passes through the copper tube and acquires the heat, and then this heat is transferred to

the storage tank and thus the temperature of the storage tank rises. At that day 19 May, the ambient temp of water is 34 at 9.00am and it reaches his maximum level of 75 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period. During this process the flow rate of water through the collector is 0.083kgps. At any moment, the collector water temperature has been greater than that of storage tank water temperature.

Table 5.5: Performance data in glass mirror concentrator (Glazed tube) by using Manual Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/ ()	System efficiency	Overall thermal efficiency
253.75	24.41	46.87	
192.5	13.37	25.13	
166.25	7.59	17.36	
105.00	6.09	11.39	22.52

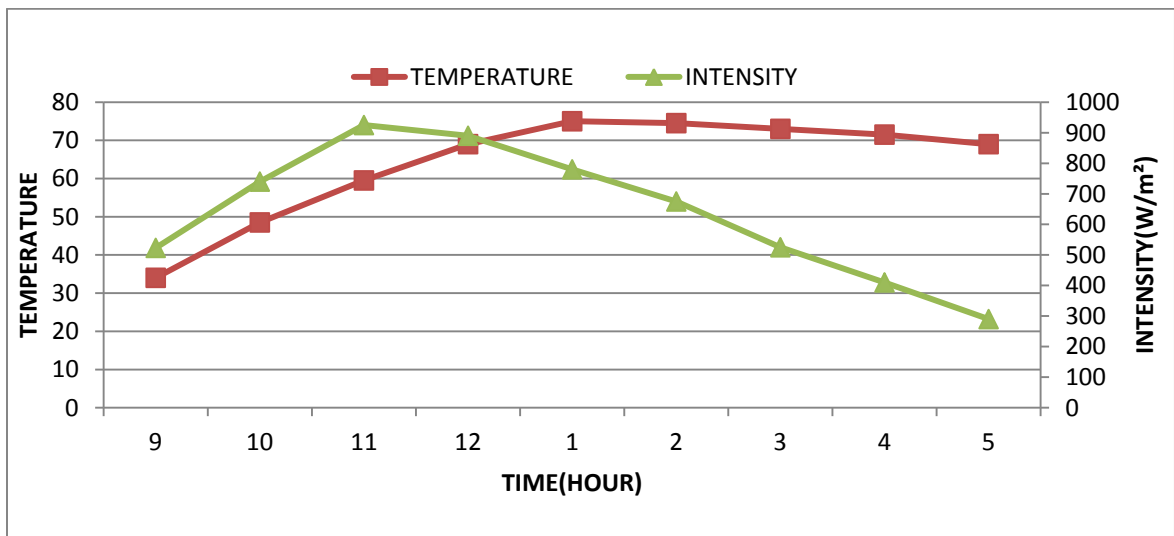


Figure 5.5 Variation of collector water temperature outlet temperature, , and beam radiation I with time

Figure 5.5 shows the variation of collector water outlet temperature, T_{co} , and beam radiation I with time on one day, viz. 19 May, 2013. The collector water outlet temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

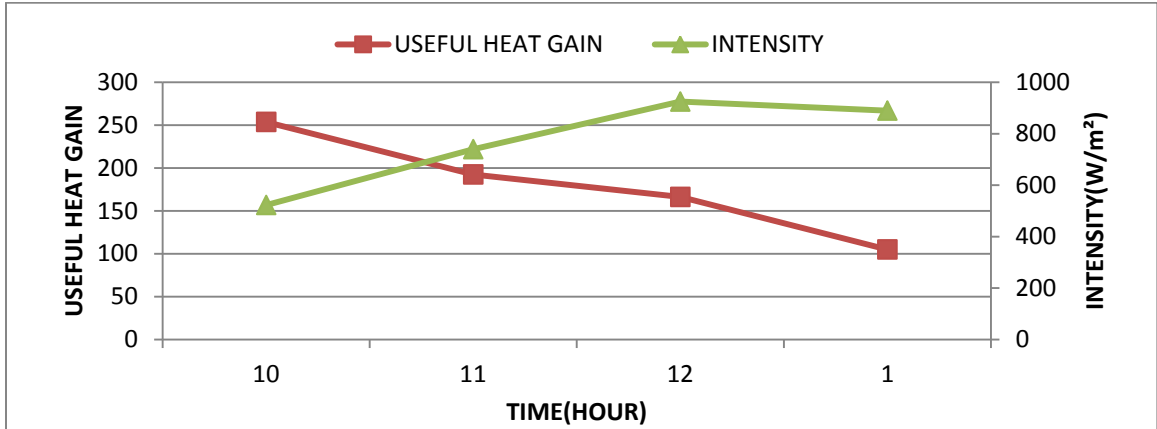


Figure 5.6 Variation of useful heat gain, Q_u , and beam radiation, I , with time

The variation of useful heat gain, Q_u , and beam radiation, I , with time is shown in the figure 5.6. It is seen that a smooth variation of beam radiation, and attain maximum temperature (925) around noon. The useful heat gain first increase from morning, and reach a peak value, and after then start decreases. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

Figure 5.7 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency decreases with time and solar intensity increases. The hourly system efficiency (thermal efficiency) decreases per hour as useful heat gain decreases continuously.

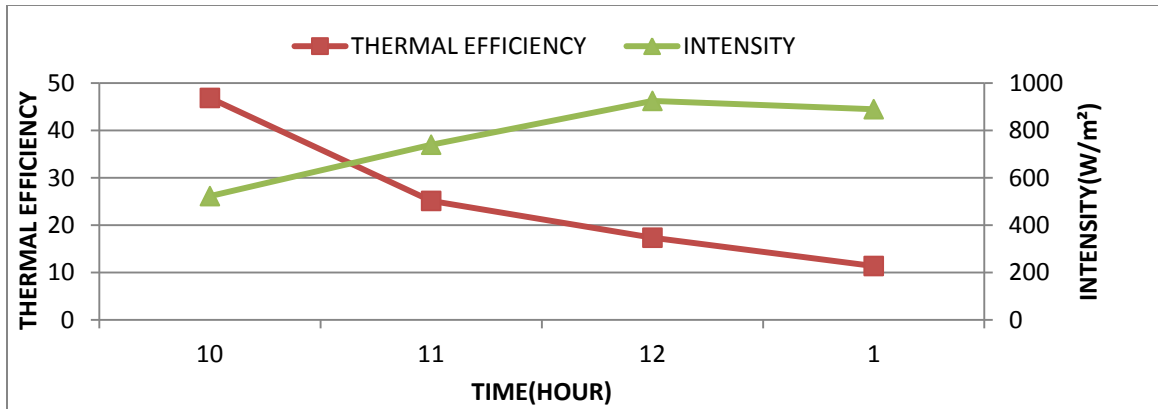


Figure 5.7 Variation of Thermal Efficiency and intensity with time

Concluded Points

- 1) The maximum temperature rise in bare tube is 68.5 and glazed tube is 75. So Glazed tube gives more temperature rise in comparison to bare tube.
- 2) Useful heat gain per hour is more in glazed tube as compare to bare tube. The maximum useful heat gain per hour in glazed tube is 253.75 at morning time.
- 3) Glazed tube gives more instantaneous efficiency as fewer losses are encountered. The maximum instantaneous efficiency in glazed tube is 24.41%.
- 4) The maximum thermal efficiency in bare tube is 40.69% and glazed tube is 46.87% as shown in the graph.
- 5) Overall system efficiency of glazed tube is 4.86% more as compare to bare tube.

5.8 Experimental study of Glass Mirror with bare copper tube when the parabola is standing at fixed position

In this experimental reading, Parabola is standing at that position when the sun gives more radiation. During performing manual reading it was found that the sun gives more radiation in between 11 am to 12 am at an angle 120-110.

Reflective material	=	Glass Mirror
Reflectivity of Glass	=	0.93
Absorber Tube	=	Copper Tube
Diameter of Copper Tube	=	28 mm
Area	=	1.1163 m ²

Table 5.6: Temperature variation of Glass Mirror by taking Intensity (bare Tube)

TIME (Hour)	INTENSITY I_b (W/m²)	TEMP. OUT °C	TEMP. IN °C	ANGLE (degree)
09-10	510	37.5	34.0	120-110
10-11	685	40.5	37.5	120-110
11-12	790	46.5	40.5	120-110
12-01	703	50.5	46.5	120-110
01-02	675	50.0	50.5	120-110
02-03	605	49.0	50.0	120-110
03-04	525	47.5	49.0	120-110
04-05	460	45.5	47.5	120-110
05-06	320	42.5	45.5	120-110

The above reading has been taken on 23 May, 2013, day is normal at morning, noon and evening.

The above table shows the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is recirculated from the storage tank and it passes through the copper tube and

acquires the heat, and then this heat is transferred to the storage tank and thus the temperature of the storage tank rises. At that day 23 May, the ambient temp of water is 34 at 9.00am and it reaches his maximum level of 50.5 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period. During this process the flow rate of water through the collector is 0.083kgps. At any moment, the collector water temperature has been greater than that of storage tank water temperature.

Table 5.7: Performance data in glass mirror concentrator (Bare tube) by using Fixed Position Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/ (%)	System efficiency	Overall thermal efficiency
61.25	7.51	10.75	
52.50	4.66	6.86	
105.00	8.08	11.90	
70.00	6.81	8.92	9.62

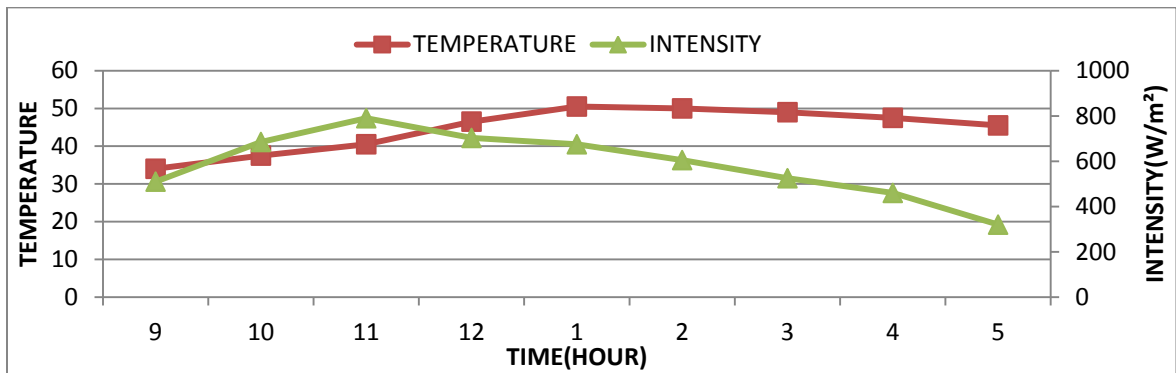


Figure 5.8 Variation of collector water outlet temperature, , and beam radiation I with time

Figure 5.8 shows the variation of collector water outlet temperature, , and beam radiation I with time on one day, viz. 23 May, 2013. The collector water outlet

temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

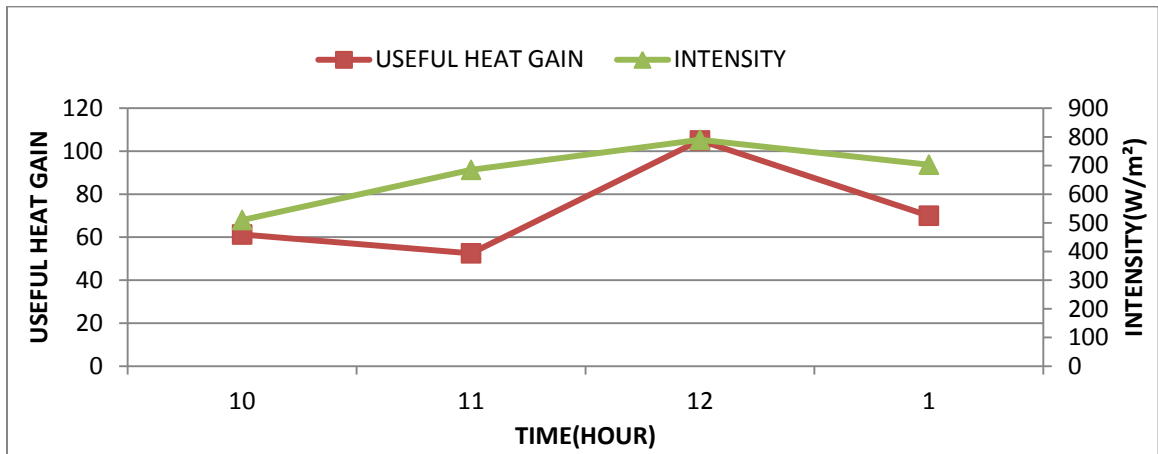


Figure 5.9 Variation of useful heat gain, , and beam radiation, I, with time

The variation of useful heat gain, , and beam radiation, I, with time is shown in the figure 5.9. It is seen that a smooth variation of beam radiation, and attain maximum temperature (790) around noon. The useful heat gain first increases from morning, and reach a peak value, and after then start decreases. It also start increases around 11 am to 12 am, when the parabola is at focusing medium. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

Figure 5.10 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency first increases from morning, and reach a peak value, and after then start decreases. It also starts increases around 11 am to 12 am, when the parabola is at focusing medium. The hourly system efficiency (thermal efficiency) decreases per hour as useful heat gain decreases continuously.

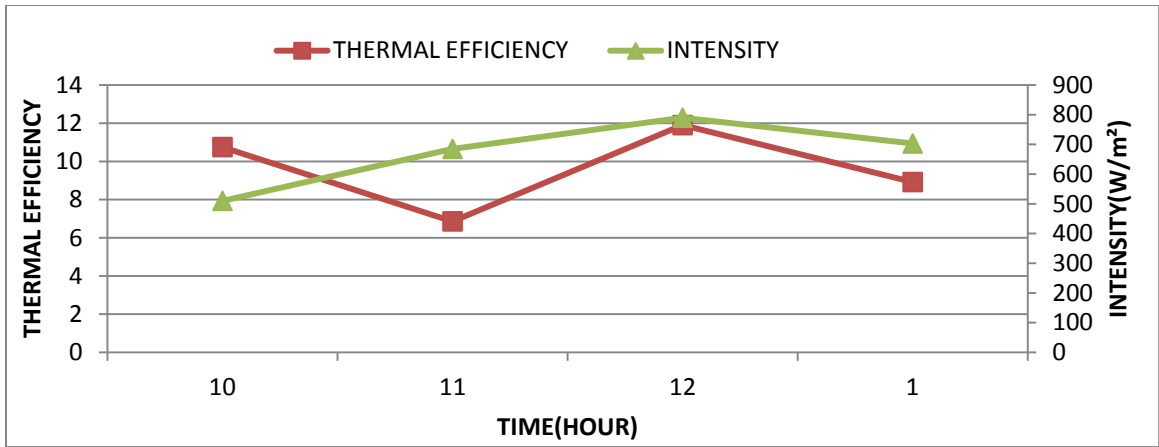


Figure 5.10 Variation of Thermal Efficiency and intensity with time

5.9 Experimental study of Glass Mirror with Glazed copper tube when the parabola is standing at fixed position

In this experimental reading, Parabola is standing at that position when the sun gives more radiation. During performing manual reading it was found that the sun gives more radiation in between 11 am to 12 am at an angle 120-110.

Reflective material	=	Glass Mirror
Reflectivity of Glass	=	0.93
Absorber Tube	=	Copper Tube
Diameter of Copper Tube	=	28 mm
Glazing material	=	Glass tube
Glass tube diameter	=	66mm
Area	=	1.035 m ²

Table 5.8: Temperature variation of Glass Mirror by taking Intensity (Glazed Tube)

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C	ANGLE (degree)
09-10	525	39.0	34.0	120-110
10-11	706	42.5	39.0	120-110
11-12	810	50.5	42.5	120-110
12-01	776	56.0	50.5	120-110
01-02	683	55.5	56.0	120-110
02-03	602	54.0	55.5	120-110
03-04	523	52.5	54.0	120-110
04-05	472	50.5	52.5	120-110
05-06	332	47.0	50.5	120-110

The above reading has been taken on 24 May, 2013, day is normal at morning, noon and evening.

Glazed means a glass tube is fitted around the copper tube to prevent the conduction convection and radiation losses. The above table shows the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is recirculated from the storage tank and it passes through the copper tube and acquires the heat, and then this heat is transferred to the storage tank and thus the temperature of the storage tank rises. At that day 24 May, the ambient temp of water is 34 at 9.00am and it reaches his maximum level of 56 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period. During this process the flow rate of water through the collector is 0.083 kgps.

Table 5.9: Performance data in glass mirror concentrator(Glazed tube) by using Fixed Position Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/ (%)	System efficiency	Overall thermal efficiency
87.50	9.12	16.10	
61.25	4.97	8.38	
140.0	8.67	16.69	
96.25	7.40	11.98	13.20

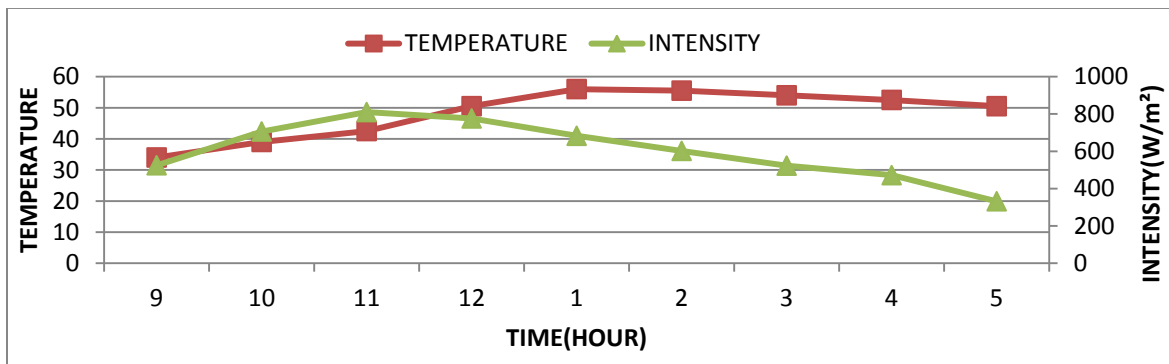


Figure 5.11 Variation of collector water temperature outlet temperature, , and beam radiation I with time

Figure 5.11 shows the variation of collector water outlet temperature, T_{co} , and beam radiation I with time on one day, viz. 24 May, 2013. The collector water outlet temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

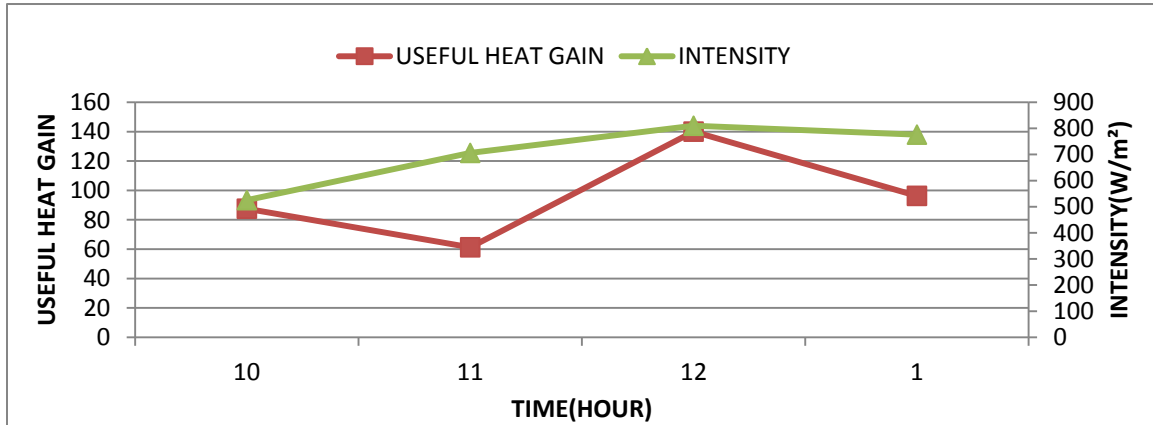


Figure 5.12 Variation of useful heat gain, T_{co} , and beam radiation, I , with time

The variation of useful heat gain, T_{co} , and beam radiation, I , with time is shown in the figure 5.12. It is seen that a smooth variation of beam radiation, and attain maximum temperature (776) around noon. The useful heat gain first increases from morning, and reach a peak value, and after then start decreases. It also start increases around 11 am to 12 am, when the parabola is at focusing medium. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

Figure 5.13 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency first increases from morning, and reach a peak value, and after then start decreases. It also starts increases around 11 am to 12 am, when the

parabola is at focusing medium. The hourly system efficiency (thermal efficiency) decreases per hour as useful heat gain decreases continuously.

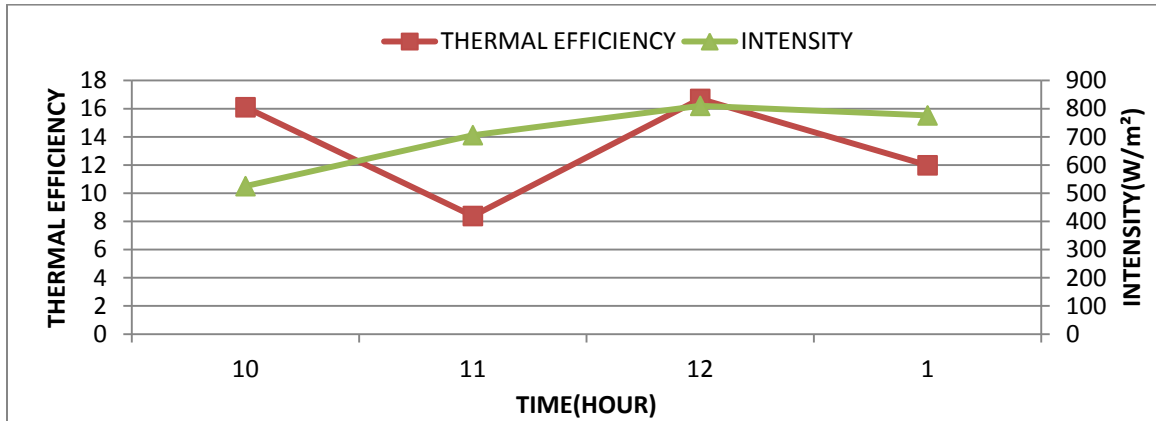


Figure 5.13 Variation of Thermal Efficiency and intensity with time

Concluded Points:

- 1) The maximum temperature rise in bare tube is 50.5 and glazed tube is 56. So Glazed tube gives more temperature rise in comparison to bare tube.
- 2) Useful heat gain per hour is more in glazed tube as compare to bare tube. The maximum useful heat gain per hour in glazed tube is 140 at morning time.
- 3) Glazed tube gives more instantaneous efficiency as less losses are encountered. The maximum instantaneous efficiency in glazed tube is 9.12%.
- 4) The maximum thermal efficiency in bare tube is 11.90% and glazed tube is 16.69% as shown in the graph.
- 5) Overall system efficiency of glazed tube is 3.58% more as compare to bare tube.

5.10 Experimental study Of Glass Mirror with bare copper tube by using Automatic Tracking Mechanism

Reflective material	=	Glass Mirror
Reflectivity of Glass	=	0.93
Absorber Tube	=	Copper Tube
Diameter of Copper Tube	=	28 mm
Area	=	1.1163 m ²

Table 5.10: Temperature variation of Glass Mirror by taking Intensity (Bare Tube), Dated 20 June, 2013

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C
09-10	515	50	34
10-11	713	62	50
11-12	894	72.5	62
12-01	868	78	72.5
01-02	778	77.5	78
02-03	662	76	77.5
03-04	530	74	76
04-05	428	71.5	74
05-06	327	68.5	71.5

Table 5.11: Temperature variation of Glass Mirror by taking Intensity (Bare Tube), Dated 21 June, 2013

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C
09-10	508	49.5	34
10-11	698	61	49.5
11-12	875	70.5	61
12-01	836	76	70.5

01-02	775	75.5	76
02-03	670	74	75.5
03-04	537	72.5	74
04-05	410	70	72.5
05-06	336	67	70

The above reading has been taken on 20 June and 21 June, 2013, days is normal at morning, noon and evening. In the above tables, 20 June reading gives the more temperature output as compare to 21 June reading. So 20 June reading is used in the calculation purpose.

The above tables show the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is recirculated from the storage tank and it passes through the copper tube and acquires the heat, and then this heat is transferred to the storage tank and thus the temperature of the storage tank rises. At that day 20 June, the ambient temp of water is 34 at 9.00am and it reaches his maximum level of 78.0 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period. During this process the flow rate of water through the collector is 0.083kgps.

Table 5.12: Performance data in glass mirror concentrator (Bare tube) by using Automatic Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/)	System efficiency	Overall thermal efficiency
280	26.03	48.70	
210	15.22	26.38	
183.75	8.92	18.41	
96.25	6.61	9.93	23.06

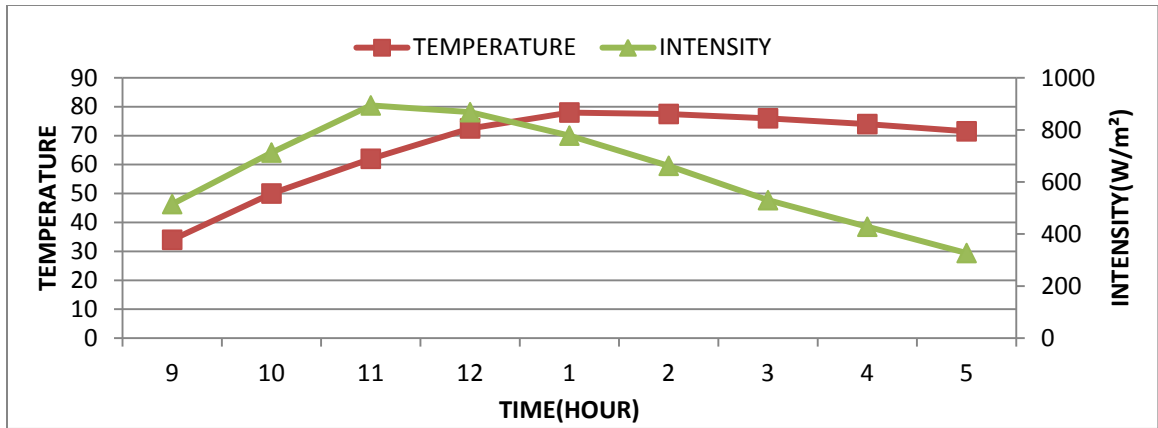


Figure 5.14 Variation of collector water temperature outlet temperature, , and beam radiation I with time

Figure 5.14 shows the variation of collector water outlet temperature, , and beam radiation I with time on one day, viz. 20 June, 2013. The collector water outlet temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

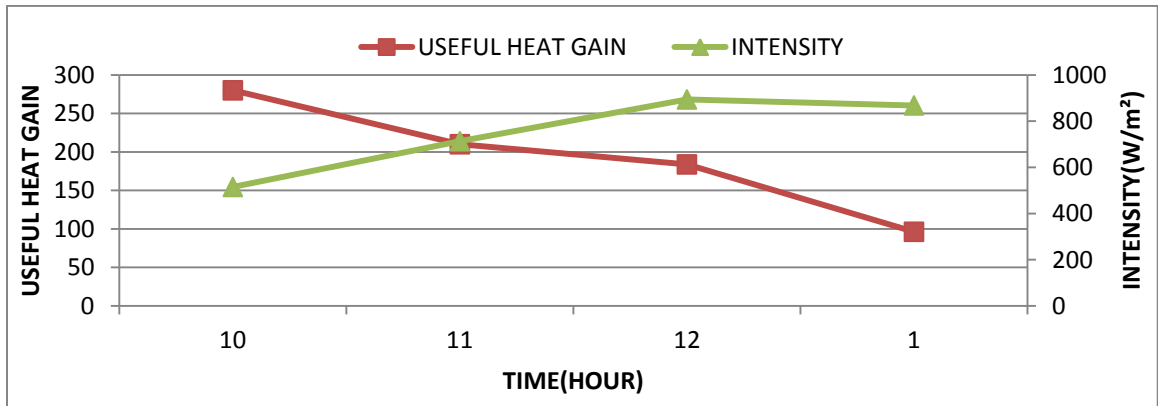


Figure 5.15 Variation of useful heat gain, , and beam radiation, I, with time

The variation of useful heat gain, , and beam radiation, I, with time is shown in the figure 5.15. It is seen that a smooth variation of beam radiation, and attain maximum temperature (894) around noon. The useful heat gain first increases from morning, and reach a peak value, and after then start decreases. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

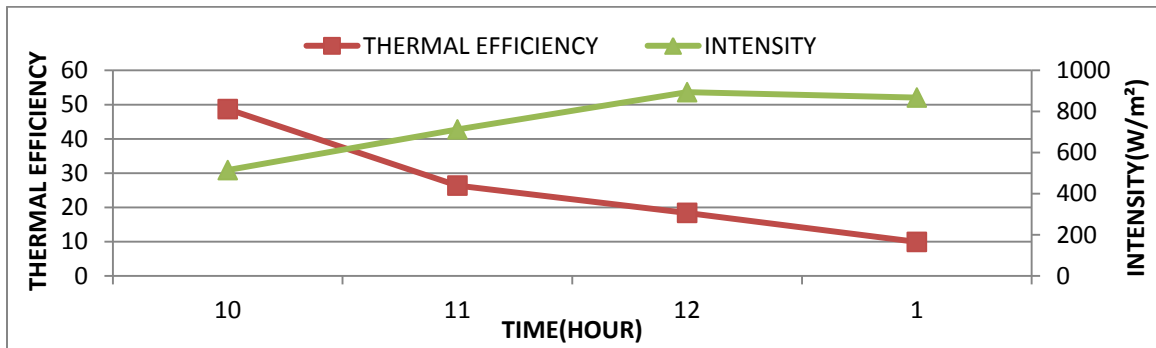


Figure 5.16 Variation of Thermal Efficiency and intensity with time

Figure 5.16 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency decreases with time and solar intensity increases. The hourly system efficiency (thermal efficiency) decreases per hour as useful heat gain decreases continuously.

5.11 Experimental study of Glass Mirror with glazed copper tube by using Automatic Tracking Mechanism

Reflective material	=	Glass Mirror
Reflectivity of Glass	=	0.93
Absorber Tube	=	Copper Tube
Diameter of Copper Tube	=	28 mm
Glazing material	=	Glass tube
Glass tube diameter	=	66mm
Area	=	1.035 m ²

Table 5.13: Temperature variation of Glass Mirror by taking Intensity (Glazed Tube), Dated 22 June, 2013

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C
09-10	515	51	33.5
10-11	690	64.5	51
11-12	892	75.5	64.5
12-01	863	82	75.5
01-02	780	81.5	82
02-03	667	80.5	81.5
03-04	546	78.5	80.5
04-05	442	76	78.5
05-06	328	72	76

Table 5.14: Temperature variation of Glass Mirror by taking Intensity (Glazed Tube), Dated 24 June, 2013

TIME (Hour)	INTENSITY I_b (W/m ²)	TEMP. OUT °C	TEMP. IN °C
09-10	536	54	35.5
10-11	728	68	54

11-12	906	78.5	68
12-01	878	85	78.5
01-02	772	84	85
02-03	665	82.5	84
03-04	547	80.5	82.5
04-05	423	77.5	80.5
05-06	345	74	77.5

The above reading has been taken on 22 June and 24 June, 2013, days is normal at morning, noon and evening. In the above tables, 24 June reading gives the more temperature output as compare to 21 June reading. So 24 June reading is used in the calculation purpose.

The above tables show the variation of solar intensity and the collector water outlet temperature. The collector water outlet temperature varies with respect to solar intensity. The water is circulated from the storage tank and it passes through the copper tube and acquires the heat, and then this heat is transferred to the storage tank and thus the temperature of the storage tank rises. Dated, 24 June, the ambient temp of water is 35.5 at 9.00am and it reaches his maximum level of 85.0 at 1.00pm and after 1.00pm the water temperature start decreases. And no energy is retreat during the collection period.

Table 5.15: Performance data in glass mirror concentrator (Glazed tube) by using Automatic Tracking Mechanism

Useful heat gain (W)	Instantaneous efficiency/)	System efficiency	Overall thermal efficiency
323.75	27.39	58.35	
245.00	16.22	32.51	
183.75	9.16	19.59	
113.75	7.27	12.51	27.45

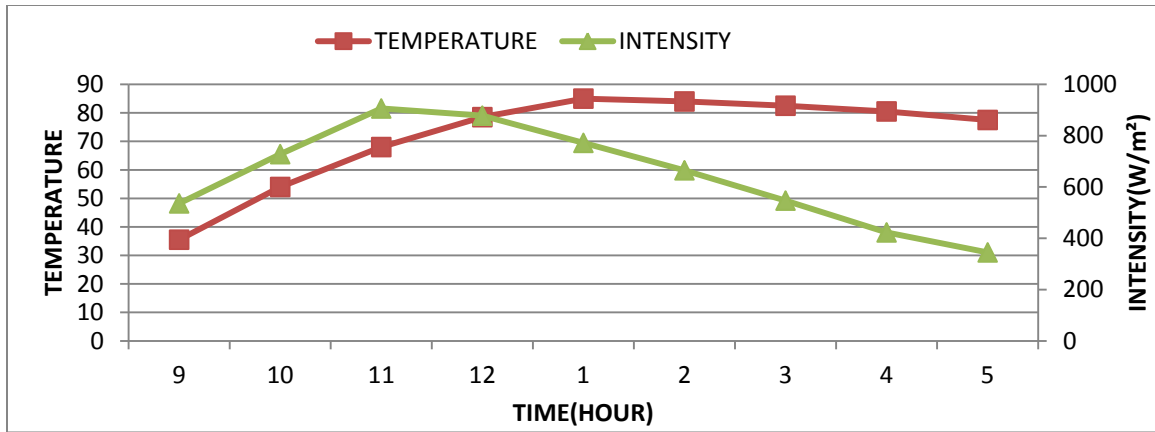


Figure 5.17 Variation of collector water temperature outlet temperature, , and beam radiation I with time

Figure 5.17 shows the variation of collector water outlet temperature, , and beam radiation I with time on one day, viz. 24 June, 2013. The collector water outlet temperature increases progressively with time, which varies from 9.00 am to 6.00 pm, and the solar intensity also varies with time.

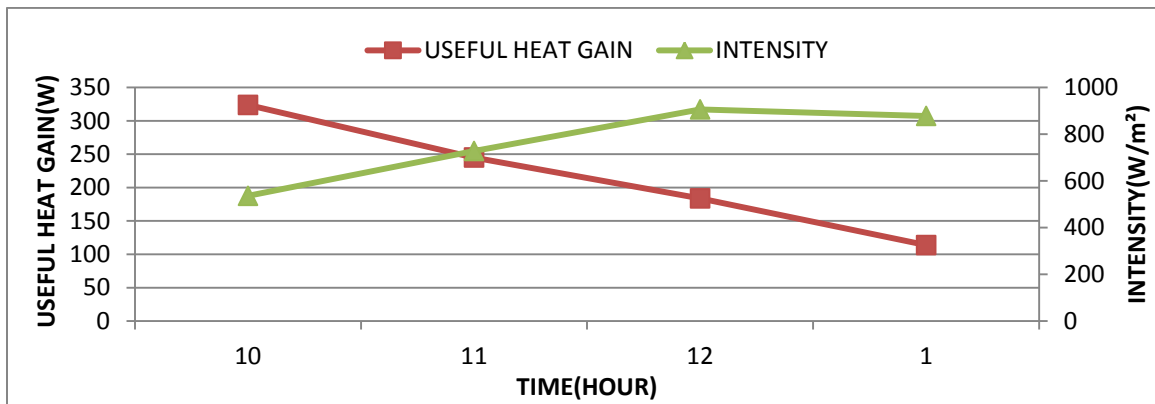


Figure 5.18 Variation of useful heat gain, , and beam radiation, I, with time

The variation of useful heat gain, , and beam radiation, I, with time is shown in the figure 5.18. It is seen that a smooth variation of beam radiation, and attain maximum temperature (906) around noon. The useful heat gain first increases from morning, and reach a peak value, and after then start decreases. This is due to the fact that the useful heat gain is strongly influenced by the solar radiation and follows its path, mean all variation dependants on solar radiation.

The collector instantaneous efficiency is calculated by using equation (5.9). it will be found that the general pattern of variation of efficiency over a day is same as that of the useful heat gain because the value of efficiency depends on both the incident beam radiation and the useful heat gain.

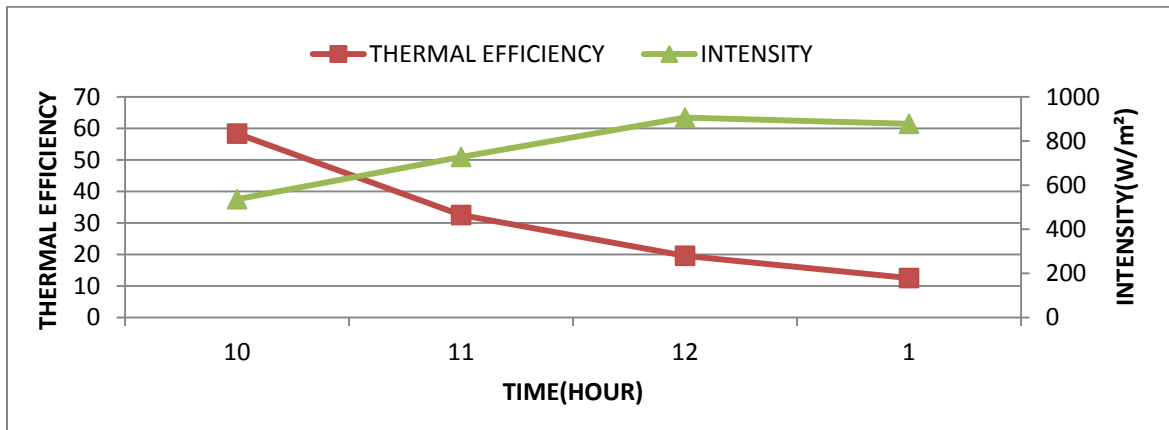


Figure 5.19 Variation of Thermal Efficiency and intensity with time

Figure 5.19 shows the variation of the thermal efficiency, and intensity with respect to time. The Thermal efficiency decreases with time and solar intensity increases. The hourly system efficiency decreases per hour as useful heat gain decreases continuously.

Concluded Points

- 1) The maximum temperature rise in bare tube is 78 and glazed tube is 85 So Glazed tube gives more temperature rise in comparison to bare tube.
- 2) Useful heat gain per hour is more in glazed tube as compare to bare tube. The maximum useful heat gain per hour in glazed tube is 323.75 at morning time.
- 3) Glazed tube gives more instantaneous efficiency as less losses are encountered. The maximum instantaneous efficiency in glazed tube is 27.39%.
- 4) The maximum thermal efficiency in bare tube is 48.70% and glazed tube is 58.35% as shown in the graph.
- 5) Overall system efficiency of glazed tube is 4.39% more as compare to bare tube.

RESULTS AND DISCUSSION

6.1 General

Thermal performance tests of a Parabolic Trough Collector are normally used to calculate its instantaneous efficiency at whole day. A common method of testing the efficiency of a solar collector employs an oil circulating system in which the temperature rise across the collector is measured under steady state conditions. Along with the inlet and outlet collector fluid temperatures, the fluid mass flow rate and the instantaneous irradiance as measured as well.

The above procedure in experimental analysis like maximum temperature rise, and performance data like instantaneous efficiency, useful heat gain, thermal efficiency and overall system efficiency of prototype parabolic trough collector are used.

Results are given in table 6.1 as shown below

Table 6.1: Values of different performance parameter

SR NO.	TRACKING MECHANISM	ABSORBER TUBE	(MAX)	(MAX)	(MAX)	
1.	Manual Tracking (one axis)	BARE Cu TUBE	68.5	22.10	40.69	17.66
		Cu TUBE WITH GLAZING	75.0	24.41	46.87	22.52
2.	Fixed Position	BARE Cu TUBE	50.5	8.08	11.90	9.62
		Cu TUBE WITH GLAZING	56.0	9.12	16.69	13.20
3.	Automatic Tracking (two axis)	BARE Cu TUBE	78.0	26.03	48.70	23.06
		Cu TUBE WITH GLAZING	85.0	27.39	58.35	27.45

Table 6.2: Comparison of maximum Temperature by different Tracking Mechanism

Sr. No.	TRACKING MECHANISM	ABSORBER TUBE	TEMPERATURE
1.	Manual Tracking (one axis)	Bare Tube	Maximum temperature rise is 68.5 .
		Glazed Tube	Maximum temperature rise is 75.0 .
2.	Fixed Position	Bare Tube	Maximum temperature rise is 50.5 .
		Glazed Tube	Maximum temperature rise is 56.0 .
3.	Automatic Tracking (two axis)	Bare Tube	Maximum temperature rise is 78.0 .
		Glazed Tube	Maximum temperature rise is 85.0 .

Table 6.2 shows the maximum temperature rise by different tracking mechanism namely manual, fixed position and automatic with bare and glazed copper tube as an absorber tube. The maximum temperature rise is 85.0 by automatic tracking mechanism in glazed copper tube. Minimum temperature is obtained by fixed position tracking mechanism. Figure 6.1 and 6.2 shows the variation of temperature by different tracking mechanism with bare and glazed copper tube and with time.

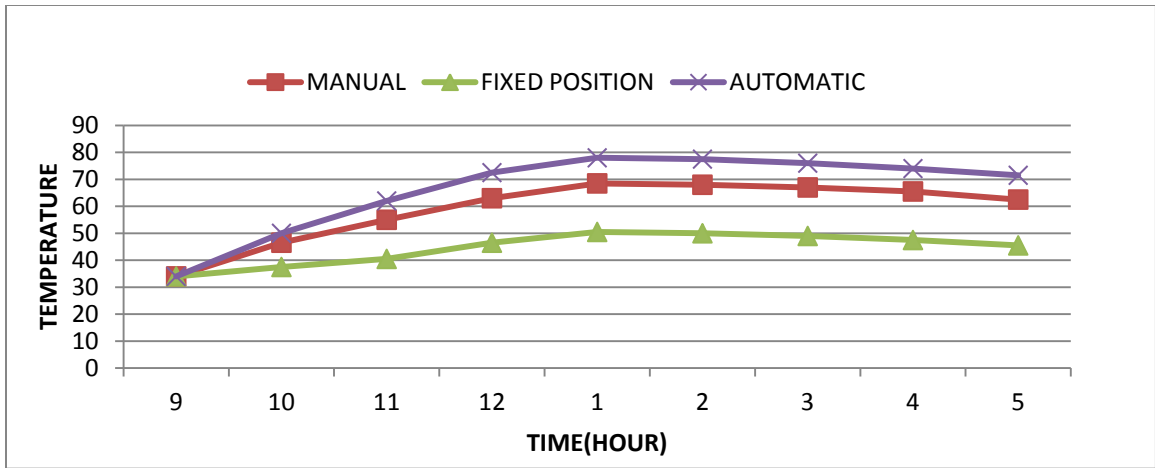


Figure 6.1 Variation of temperature by using different tracking mechanism with bare copper tube

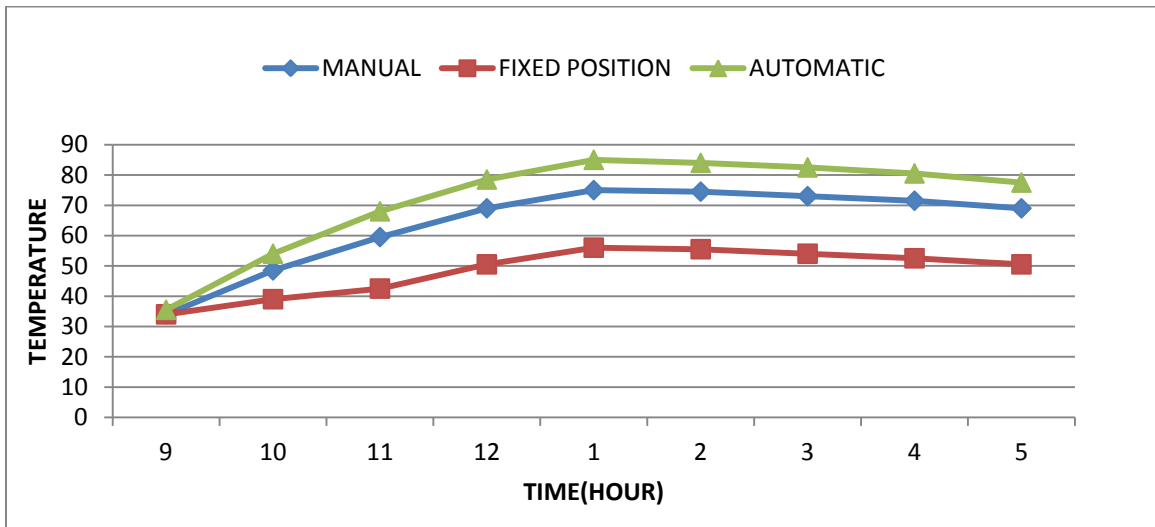


Figure 6.2 Variation of temperature by using different tracking mechanism with glazed copper tube

Table 6.3: Comparison of maximum Useful Heat Gain by different Tracking Mechanism

Sr. No.	TRACKING MECHANISM	ABSORBER TUBE	USEFUL HEAT GAIN (W) per hour
1.	Manual Tracking (one axis)	Bare Tube	Maximum Useful Heat Gain is 227.5 W.
		Glazed Tube	Maximum Useful Heat Gain is 253.75 W.
2.	Fixed Position	Bare Tube	Maximum Useful Heat Gain is 105 W.
		Glazed Tube	Maximum Useful Heat Gain is 140 W.
3.	Automatic Tracking (two axis)	Bare Tube	Maximum Useful Heat Gain is 280 W.
		Glazed Tube	Maximum Useful Heat Gain is 323.75 W.

Table 6.3 shows the maximum Useful Heat Gain (W) by different tracking mechanism namely manual, fixed position and automatic with bare and glazed copper tube as an absorber tube. The maximum Useful Heat Gain is 323.75 W per hour by automatic tracking mechanism in glazed copper tube. Minimum Useful Heat Gain per hour is obtained by fixed position tracking mechanism. Figure 6.3 and 6.4 shows the variation of Useful Heat Gain by different tracking mechanism with bare and glazed copper tube and with time.

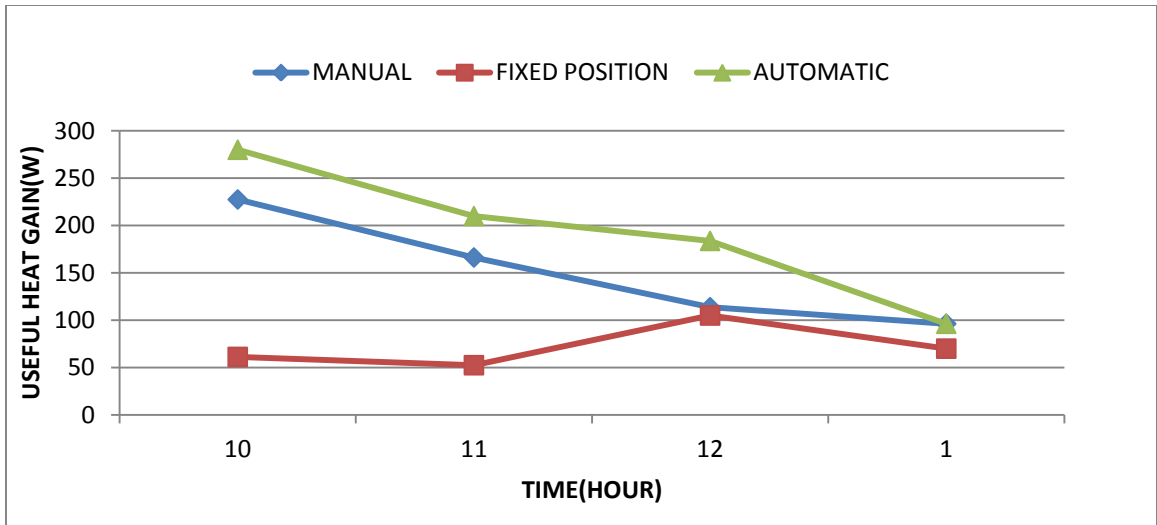


Figure 6.3 Variation of Useful Heat Gain by using different tracking mechanism with bare copper tube

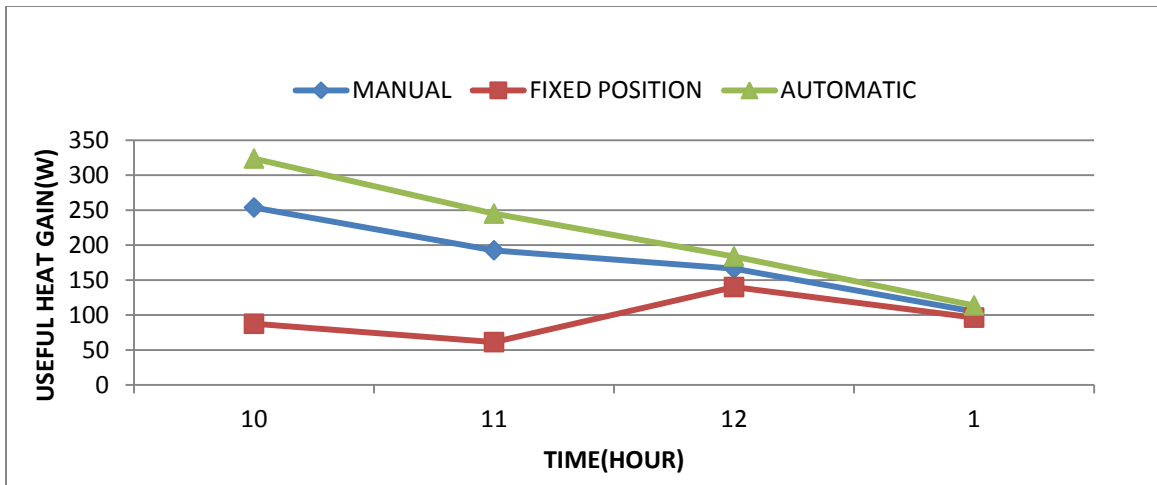


Figure 6.4 Variation of Useful Heat Gain by using different tracking mechanism with glazed copper tube

Table 6.4: Comparison of maximum Instantaneous Efficiency by different Tracking Mechanism

Sr. No.	TRACKING MECHANISM	ABSORBER TUBE	INSTANTANEOUS EFFICIENCY
1.	Manual Tracking (one axis)	Bare Tube	Maximum instantaneous efficiency is 22.10%
		Glazed Tube	Maximum instantaneous efficiency is 24.41%
2.	Fixed Position	Bare Tube	Maximum instantaneous efficiency is 8.08%
		Glazed Tube	Maximum instantaneous efficiency is 9.12%
3.	Automatic Tracking (two axis)	Bare Tube	Maximum instantaneous efficiency is 26.03%
		Glazed Tube	Maximum instantaneous efficiency is 27.39%

Table 6.4 shows the maximum Instantaneous Efficiency by different tracking mechanism namely manual, fixed position and automatic with bare and glazed copper tube as an absorber tube. The maximum Instantaneous Efficiency is 27.39% by automatic tracking mechanism in glazed copper tube. Minimum Instantaneous Efficiency is obtained by fixed position tracking mechanism. Figure 6.5 and 6.6 shows the variation of Instantaneous Efficiency by different tracking mechanism with bare and glazed copper tube and with time.

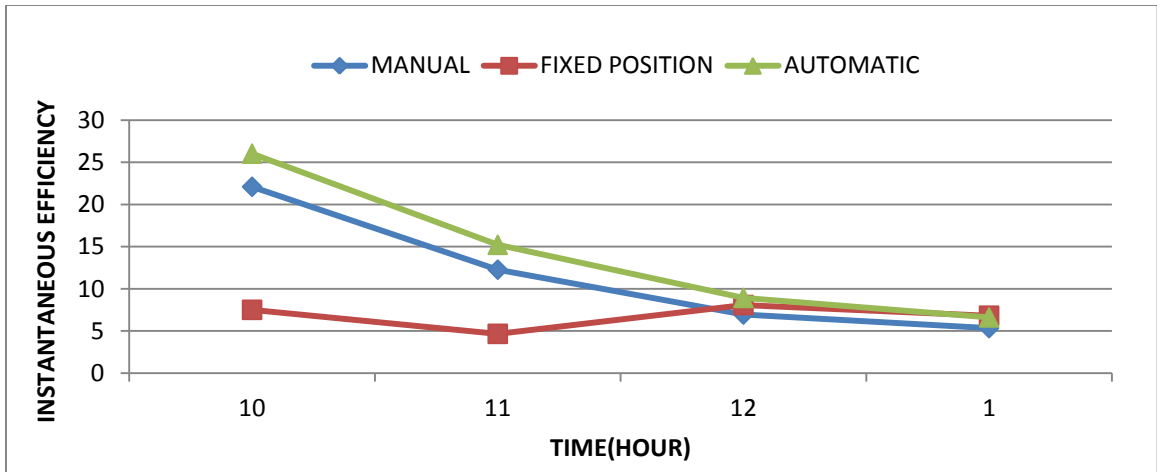


Figure 6.5 Variation of Instantaneous Efficiency by different tracking mechanism with bare copper tube

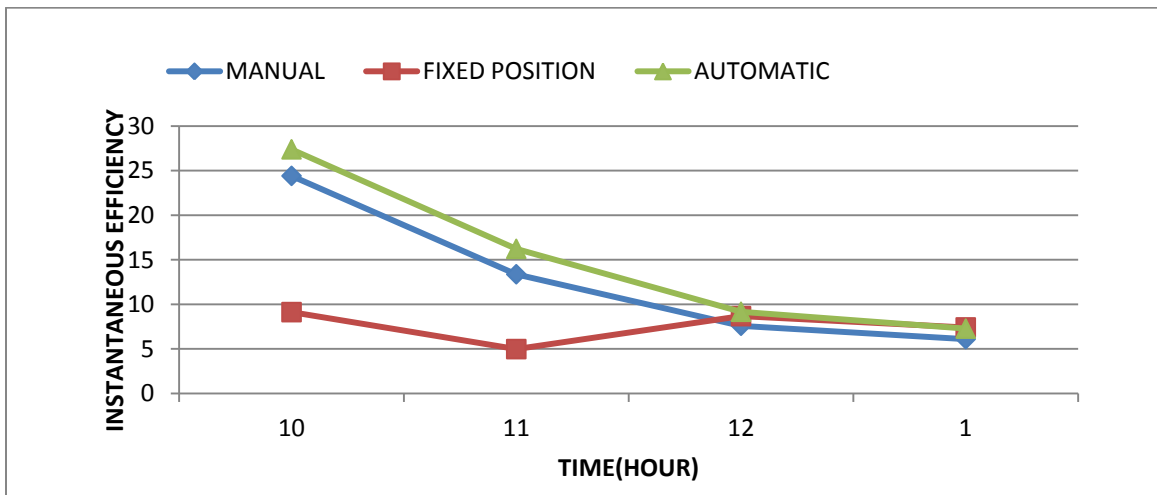


Figure 6.6 Variation of Instantaneous Efficiency by different tracking mechanism with glazed copper tube

Table 6.5: Comparison of maximum Thermal Efficiency by different Tracking Mechanism

Sr. No.	TRACKING MECHANISM	ABSORBER TUBE	THERMAL EFFICIENCY
1.	Manual Tracking (one axis)	Bare Tube	Maximum thermal efficiency is 40.69%
		Glazed Tube	Maximum thermal efficiency is 46.87%
2.	Fixed Position	Bare Tube	Maximum thermal efficiency is 11.90%
		Glazed Tube	Maximum thermal efficiency is 16.69%
3.	Automatic Tracking (two axis)	Bare Tube	Maximum thermal efficiency is 48.70%
		Glazed Tube	Maximum thermal efficiency is 58.35%

Table 6.5 shows the maximum Thermal Efficiency by different tracking mechanism namely manual, fixed position and automatic with bare and glazed copper tube as an absorber tube. The maximum Thermal Efficiency is 58.35% by automatic tracking mechanism in glazed copper tube. Minimum Thermal Efficiency is obtained by fixed position tracking mechanism. Figure 6.7 and 6.8 shows the variation of Instantaneous Efficiency by different tracking mechanism with bare and glazed copper tube and with time.

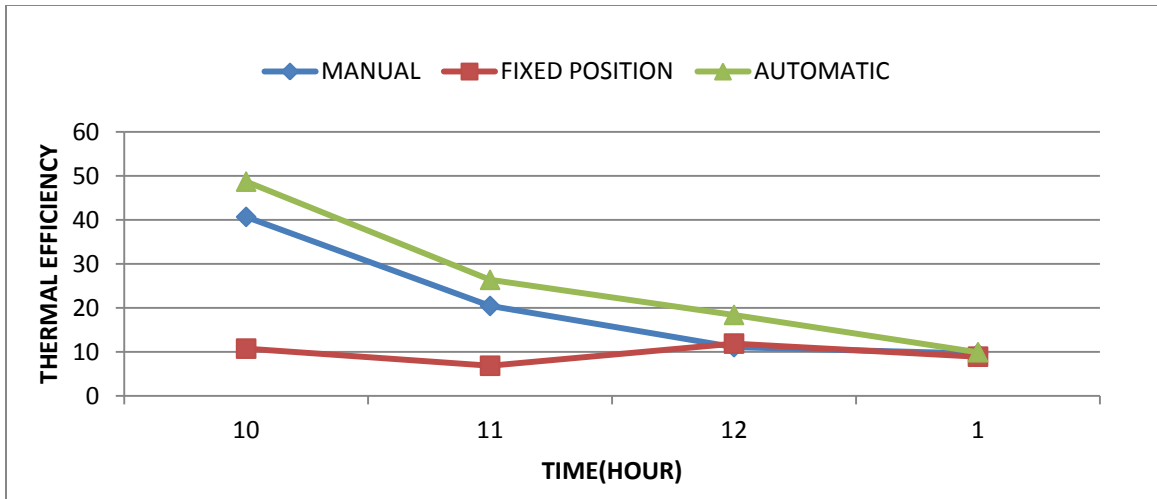


Figure 6.7 Variation of Thermal Efficiency by different tracking mechanism with bare copper tube

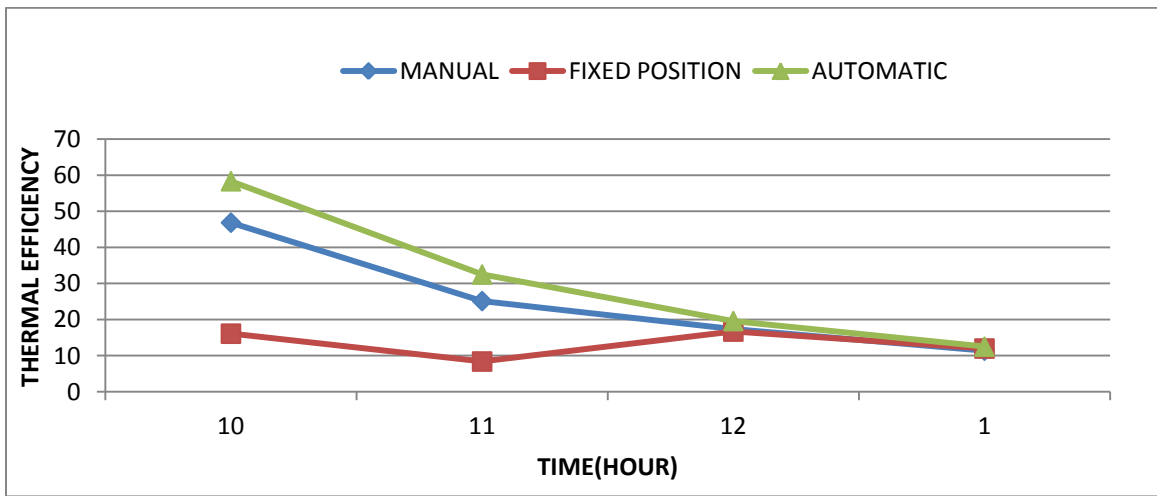


Figure 6.8 Variation of Thermal Efficiency by different tracking mechanism with glazed copper tube

Table 6.6: Comparison of Overall Thermal Efficiency by different Tracking Mechanism

Sr. No.	TRACKING MECHANISM	ABSORBER TUBE	OVERALL THERMAL EFFICIENCY
1.	Manual Tracking (one axis)	Bare Tube	Maximum Overall thermal efficiency is 17.66%
		Glazed Tube	Maximum Overall thermal efficiency is 22.52%
2.	Fixed Position	Bare Tube	Maximum Overall thermal efficiency is 9.62%
		Glazed Tube	Maximum Overall thermal efficiency is 13.20%
3.	Automatic Tracking (two axis)	Bare Tube	Maximum Overall thermal efficiency is 23.06%
		Glazed Tube	Maximum Overall thermal efficiency is 40.69%

Table 6.6 shows the Overall Thermal Efficiency by different tracking mechanism namely manual, fixed position and automatic with bare and glazed copper tube as an absorber tube. The maximum Overall Thermal Efficiency is 30.01% by automatic tracking mechanism in glazed copper tube. Minimum Overall Thermal Efficiency is 9.62% by fixed position tracking mechanism in bare copper tube.

System Optical Efficiency is same for all the tracking mechanism namely manual, fixed position and automatic. In the present work, glass mirror is used as an reflective material for all the tracking mechanism. So optical efficiency is same for all the tracking mechanism.

Optical Efficiency for Tracking Mechanism = 70.63%

In the present work an experimental study is performed to investigate the effect maximum temperature obtained for different tracking mechanism namely as manual, fixed position and automatic on the parabolic trough collector. It includes design, fabrication and characterization of different tracking mechanisms. Different results are obtained by using bare copper tube and glazed copper tube as an absorber tube. The points to be concluded after experimental work are given below:

- Automatic tracking system gives the maximum temperature with glazed copper tube as compare to manual and fixed position tracking system. Maximum temperature obtained is 86 as compared to 75 in fixed and manual tracking system, and minimum temperature obtained is 50.5 by fixed position tracking system.
- Instantaneous efficiency obtained by automatic tracking system is more as compare to manual and fixed position tracking system. Automatic tracking system shows an improvement of 5-50% as compare to fixed position tracking system, and shows an improvement of 3-26% as compare to manual tracking system.
- Considering thermal efficiency per hour, automatic tracking system shows an improvement of 10-55% as compare to fixed position, and 5-20% improvement as compare to manual tracking system.
- Overall system efficiency is obtained using automatic tracking system is more as compare to manual and fixed position tracking system. It shows an improvement of 5-50% as compare to other tracking system.
- Optical Efficiency of present parabolic trough collector is same for all tracking system, because glass mirror is used as a reflective material. Optical Efficiency for our experiment is 70.63%.

- This type of solar tracking system can be placed anywhere in the world where proper sunlight is available and can be operated without any geographical data.
- There is further scope of improvement in present parabolic trough collector due to high mass flow rate which restrict further improvement in its efficiency.
- By improving condition the improvement of collector efficiency can be achieved more than 65%

CHAPTER-8

FUTURE SCOPE

The future scope of prototype parabolic trough collector is very wide. India's Power scenario of solar energy as a renewable energy source is still under research. So, there is a necessity of further theoretical as well as experimental work, investigations to enhance the efficiency of solar collector and to obtain firm and authenticate results. In the present dissertation work, feasibility of a prototype parabolic trough collector is tested for hot water generation and further practical application like air heating, process heating and further steam can be generated with more area and length.

Also improved automatic tracking system with stepper motor can also be used to track the sun with more precise steps. Problems related to solar radiation discontinuity due to clouds during automatic tracking can also be eliminated, using more advance electronics.

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