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PROPOSAL AND DESIGN OF NEW SOLAR COLLECTOR

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Abstract — *The increase trend in fuel price coupled with rising carbon dioxide concentration and energy security have encouraged the world to shift towards renewable energy sources. In recent years a nationally and internationally concern about energy production has been terrific.*
Concentrated solar power (CSP) has great prospective for hefty scale renewable energy sources, and is currently an eye catching one for its utilization with much scope in research. Especially, parabolic trough collectors (PTCs) are attractive due to their increased efficiency as compared to other point focus and line focus.
This paper is concerned with a newly developed solar collector which consists of Renovative Parabolic trough collector (PTC) along with flat facets. PTC trough will not have any tracking mechanism whereas flat reflector will track the sun. Such collector is being developed to keep PTC disadvantage of movable receiver into consideration. By newly adopted methodology to design we come to area of 6 m2 collector area to generate 1 KW of power.

***Keywords**- Solar Energy; Solar Collector; Flat Reflector; Parabolic Trough Collector; Solar thermal; Fixed Receiver*

I. INTRODUCTION

Solar radiation is the main source of the energy system of the Earth and it is the basis of all the natural cycles and events of life, including many human activities. The awareness of how the radiation is intercepted (absorbed or deflected) by the atmospheric layer that environs the Earth which is albedo effect (the fraction of it that reaches the ground and the one that comes from all directions) is a must for the understanding of natural phenomena related with climate and meteorology and the location and design of the systems that use solar energy. As renewable energy is trending nowadays due to environment impact caused by fossil fuels, In future there is huge scope of solar energy as alternative of fossil fuels. As claimed by Oussama Ibrahim et al., energy demand is continuously increasing due to global population growth and improved living standards. However, fossil fuels, the present chief energy source, are being used up in a haphazard increasing manner, even though they are non-renewable and they are not available equally in the earth. Consequently, Global warming, CO_2 Emission, environmental pollution, economic and energy security issues are horribly increasing. Based on this fact, worldwide governments and organizations are working hard to raise the share of renewable energy sources and reduce energy consumption.

Concentrating solar Power (CSP) is regarded as one of significant accomplishments for large-scale using renewable energy sources. To collect solar energy solar collectors are needed. It is mainly classified in Non-Concentrating type (flat plat type) and Concentrating type (Focusing type). Here in Focusing type there is huge scope of improvements in Parabolic Trough Collector (PTC) and Linear Fresnel Collector (LFC). So for improvements study is needed on basis of advantages and disadvantages.

II. LITERATURE REVIEW

1. The experiments were done by Syed Ameen Murtuza [1] on a scale of 12 months. Average temperatures of both inlet water and outlet water were measured. February to May gave appreciably good temperatures from 80 °C to 103 °C. Reynolds number with respect to different flow such as 0.4 LPM, 0.8 LPM and 1.2 LPM was calculated in order to predict flow pattern in the receiver tube.

2. The maximum expected energy loss during summer is 10%, protecting the installation from overheating. Ray tracing shows an energy loss in summer in both cities of an 8%, close to the 10% expected. Amazingly, the reduction of the energy captured in winter in Madrid is 5% and only 3% for Alice Springs although the concentrator was designed for Madrid’s latitude. This fact can be explained by the low average radiation data observed in Madrid in December by Rodriguez-Sanchez [2].There are a few days in winter when the radiation profile for Madrid should be higher as there are clear days during the winter in Spain, which are the days the concentrator is designed for. The results of this paper

proved that the idea could work at certain latitudes, but the concentrator should be designed for specific locations or it will not be helpful.

3. J.Macedo-Valencia [3] Methodology followed is easy to adopt but they have used a massive supporting structure which can be optimized in terms of dimension and weight.

4. The performance of parabolic trough collector can be improved greatly by using one of the solar tracking techniques by Mr Arvind Kumar [4], to concentrate a direct solar beam on to a focal point. This technique depends on the tracking axis of a solar beam reflector. The solar beam is normally inclined on the aperture plane at all rimes. In this situation angle of cos component =1. It is effortless to show that at solar noon. Using the two-axis mode cannot be justified unless the amount of energy produced compensate for the additional elements and maintenance cost the focal axis is N-S and horizontal. This mode is best tracking mode for large scale power generation. The focal axis is N-S and inclined. The collector is rotated continuously. This mode have highest efficiency.

5. Due to use of storage-reduce energy costs and consumption, and size of equipment cost. Type of storage (biological storage-storage for long periods, Magnetic storage Over all storage efficiencies of 80-90% are anticipated by Ajesh vijayan [5],for super conducting storage system, Thermal energy storage -good heat transfer, long term chemical stability, no toxicity hazard, storage efficiency of latent heat is more than sensible heat, the most familiar chemical energy storage device is battery)

6. By Abhishek Agraval [6], as the angle between the sun (source) and fixed surface (CSP) is continually changing, the power density on a fixed Photovoltaic module is less than that of the incident sunlight. The beam radiation dominates throughout the year where the maximum beam radiation reaches in the month of May whereas the least amount of beam radiation occurs in month of December at village nandha, Haryana. For optimization of tilt angle, we can use isotropic models.

7. A more recent methodology for the economic optimization of the solar area in either parabolic trough or complex solar plants was carried out by Montes et al. [7]. Thermal performance for dissimilar solar power plants was studied at nominal load conditions. Once annual electric energy generation is known to us, then levelized cost of energy (LCOE) for the solar plant can be calculated, for minimum LCOE value for a certain optimum solar area.

8. Similarly, an analytic model for a solar thermal electric generating system with parabolic trough collectors was done by Rolim et al. [8]. Three fields of different collectors were considered, the first field with evacuated absorbers, the second with no evacuated absorbers and the third with bare absorbers.

III. SUMMARY OF LITERATURE REVIEW

3.1. Literature Study on Parabolic Trough Collector (PTC):-

“Table 1.Summary of Literature study on PTC”

Parameters	Reasoning
Cost	High
Efficiency	High (73% - 77%)
Land Requirement	Large
Wind Load	High
Heat transfer fluid selection	Particular
Receiver	Movable
Tracking System	Present
Storage System	Easily Available
Shading and Blocking	No

3.2. Literature Study on Linear Fresnel Collector (LFC):-

"Table 2.Summary of Literature study on LFC"

Parameters	Reasoning
Cost	Low
Efficiency	Low (50% - 55%)
Land Requirement	Low
Wind Load	Low
Heat transfer fluid (HTF) selection	Any type
Receiver	Fixed
Tracking System	Present
Storage System	No Commercial large storage
Shading and Blocking	Yes

IV. DESIGN METHODOLOGY

4.1. Introduction of New solar collector

After doing literature survey we came to an idea to combine two most successful CSP technology which is PTC and LFC. Here in our new collector, the Dis-advantages of PTC will be overcome by keeping Receiver fixed and Advantages of LFC will be summed up with PTC. PTC structure is going to be fixed that means no tracking for bulky structure. Receiver is also going to be fixed so there is no chance of HTF Leakage as well as there is no constraint to use particular HTF. We will use water as HTF for our new solar collector which is free and easily available and properties of HTF will not change. Coming on second part, Flat plate collector. Here flat plat collector is used which is light in weight and easy to manufacture is developed which will track the sun throughout the day with the help of stepper motor which is solar driven with help of solar panel. Wind losses are very low or negligible but at a same time its concentration ratio is unity. As size is distributed evenly no wind load on the structure so no wind losses and efficiency will not be effected.
New kind of Solar Collector (Renovative PTC) will be developed with following feature-

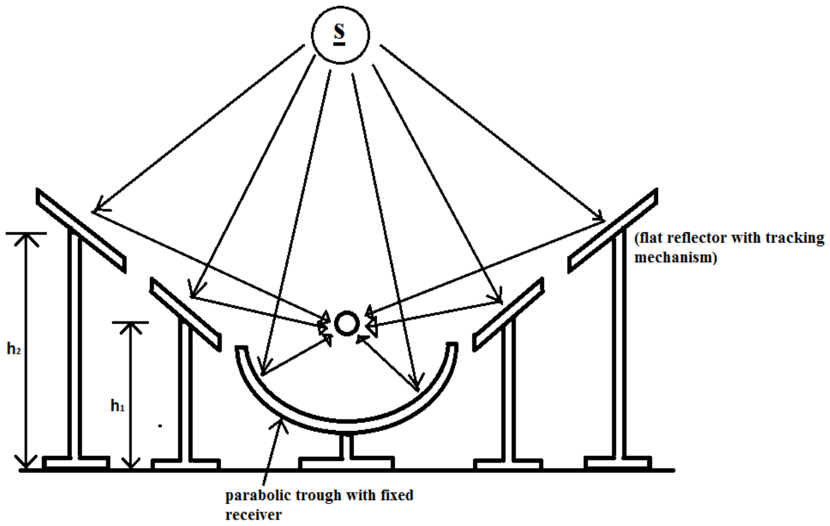
1. Fixed Receiver
2. More options to select Heat Transfer fluid (HTF)
3. No chance of HTF leakage
4. Properties of HTF will not be disturbed
5. Heat Exchanger may be eliminated

4.2. Objective of New solar collector

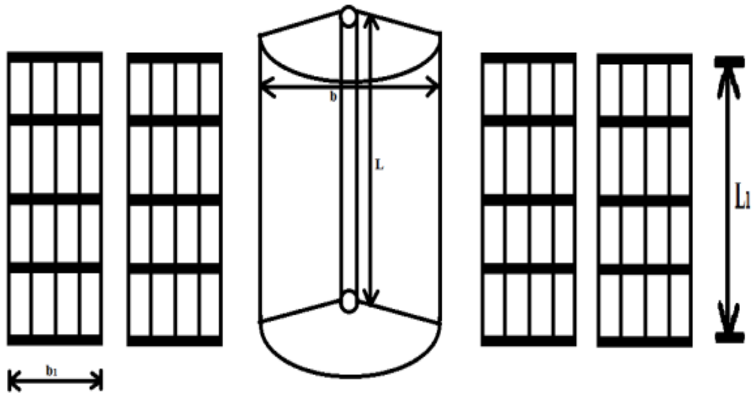
1. Compare the performance of newly developed solar collector with PTC technology by keeping Efficiency same.
2. Replacement of movable receiver with fixed receiver in PTC technology
3. Development of prototype and experimental investigation.

The whole new collector will fulfil our stated objective and solve problem with its new features.

4.3. Proposed System with Sketch



"Figure 1. Front View of Proposed System"



"Figure 2. Top View of Proposed System"

It consist of Components like:-
1. Parabolic Trough
2. Flat Plate collector
3. Fixed receiver & Glass Tube
4. Mechanical Tracking (for Flat plate collector only)
5. Solar Panel
6. Electric Motor driven by Solar power
7. Light weight supporting structure
8. Water as HTF
9. Pulleys & Bearings

Material Specification:-
1. Going to use Aluminium Sheet as a reflecting material for trough as well as for Flat Reflector.
2. For Receiver we are going to use Galvanized Iron Pipe.
3. M.S is used as a supporting structure

4.4. Design Calculation

We are going to design for unit kilowatt power as it is standard value. So taking references from any sources becomes easier. Another reason is if we go for unit watt then aperture area will be very small similarly for unit megawatt aperture area is huge.

4.4.1. Design for 1KW Power generation:-

For Designing we have done reverse engineering. i.e coming back from sink to source or in our case coming back from generator to sun input. In our case in Descending order components are Generator, Turbine, Receiver, Reflector and Sun. So as we knew Efficiency is Ratio of Output to Input. One can get Efficiency of components from Research paper and our output is fixed so we can get easily input of one component which is but obviously output of previous component. Hence in such manner we calculated values.

(1) $E_{application} = 1$ KW

From Generator 1KW is generated. Generator gets input from a turbine. So what input should be we get from this relation.

$\eta_{generator} = 95\%$ [4]

$\therefore \eta_{generator} = \frac{E_{application}}{E_{turbine}}$

$\therefore E_{turbine} = \frac{1000W}{0.95} = 1.052$ KW

(2) Thermal Efficiency means how much water is converted to steam and that steam is utilized to rotate rotor of turbine which is turbine input. Turbine input if in terms of HTF or one can say output of receiver , so from relation we get,

$\eta_{thermal}$ = 33.38 % [4]

$\eta_{turbine}$ = 60% [4]

$\rightarrow \eta_{turbine} = \frac{E_{turbine}}{E_{HTF}}$

$\therefore 0.6 = \frac{1052.632}{E_{HTF}}$

$\therefore E_{HTF}$ = 1.754 KW

Similarly using same relation for finding Input of receiver we get

$\rightarrow \eta_{thermal} = \frac{E_{HTF}}{E_{reciever}}$

$\therefore 0.3338 = \frac{1754.387}{E_{reciever}}$

$\therefore E_{reciever}$ = 5.255 KW

(3) Intercept Factor is defined as fraction of the radiation which is reflected from the concentrator and is incident on absorber.

Intercept factor = 0.94 = r [4]

Transmissivity of glass = 0.699 = τ

Absorptivity of receiver = 0.88 = α

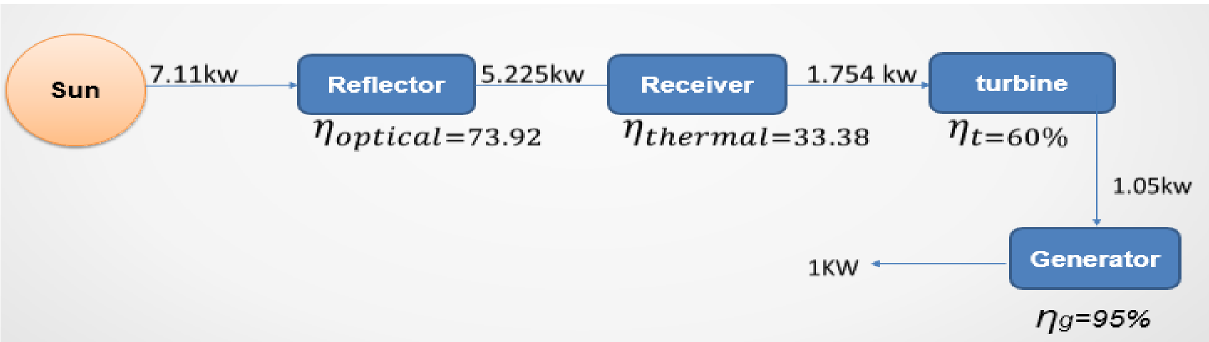
Optical efficiency is defined as the ratio of the energy absorbed by the receiver to the energy incident on the collector's aperture. The optical efficiency depends on the optical properties of the materials involved, the geometry of the collector, and the various imperfections arising from the construction of the collector.

η_o = optical efficiency = 73.92 % [4]

$\eta_o = \frac{E_{reciever}}{E_{sun}}$

$\therefore 0.7392 = \frac{5255.802}{E_{sun}}$

$\therefore E_{sun}$ = 7.110 KW



"Figure 3. Efficiency and area calculation from reverse engineering"

The collector is operating at a temperature of 150°C and Solar Power Plant producing electricity for 8 hrs. every day.

∴. Solar radiator incident on the collectors per unit day (Vataria) * thermal efficiency * generator efficiency = electricity production * hours per day

∴. 5.83 KW h/m^2 *Ac* 0.7392 * 0.338 * 0.85 = 1 KW * 8

∴. Ac= 5.7812m^2= 6 m^2

Therefore, Length of Solar Field = 2m & Aperture of concentrator = 3.657 m

4.4.2. Trough and receiver Diameter optimization

From the standard available reflective stainless steel sheets, a pilot trough-receiver unit is developed. Stainless steel sheet 2.4mx1.2m was chosen as reflecting surface. The collector is designed with simple parabolic equations. From geometrical relations of the parabolic section, equations (1), the cross section for the parabolic trough was traced as shown by figures'. The sheet was curved to form a parabolic trough module of 2.4m length and 1m aperture width with effective aperture area of 2.4m2. The simple parabolic equation in Cartesian coordinates is,

$$x^2 = 4fy \quad ..... (1)$$

From equation (1), the height of the parabola in terms of the focal length and aperture diameter is

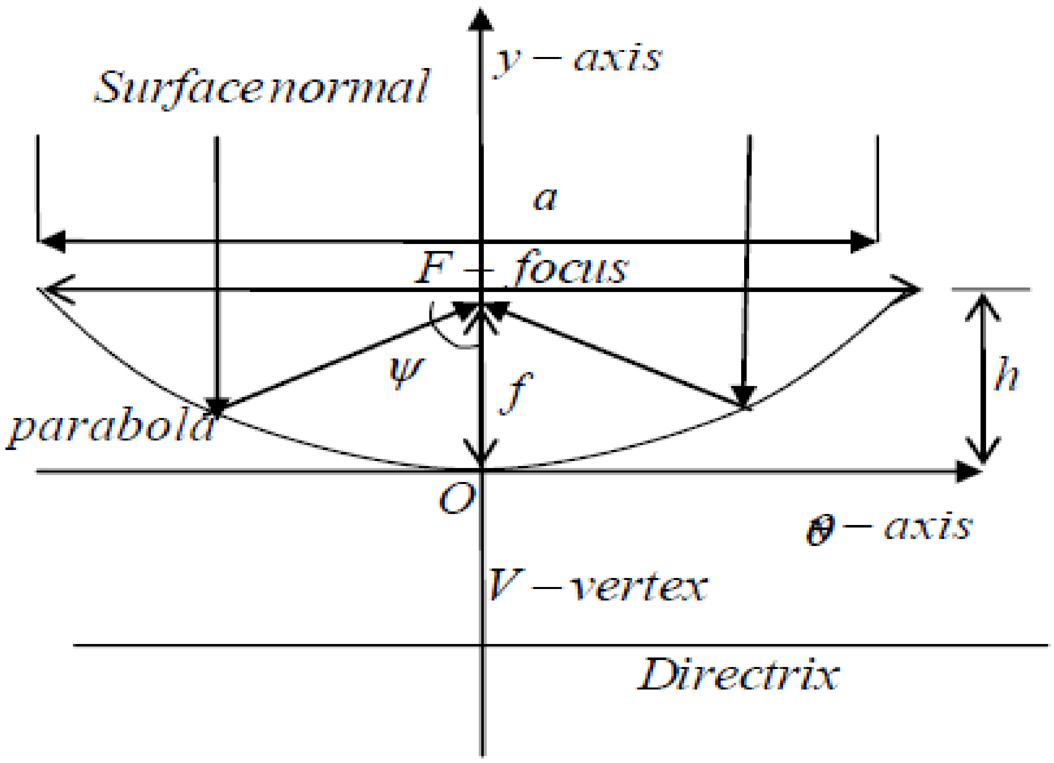
$$(a/2)2 = 4fh \quad \text{Or} \quad h = \frac{a^2}{16f} \quad . \; ....(2)$$

The rim angle ψ rim is given by:

$$\tan\frac{\psi_{rim}}{2} = \frac{a}{4f}$$

Geometrical concentration ratio Cg is defined as "the area of the collector aperture (Aa), divided by the surface area of the receiver (Ar):

$$C_g = \frac{A_a}{A_r} \quad ..... (3)$$



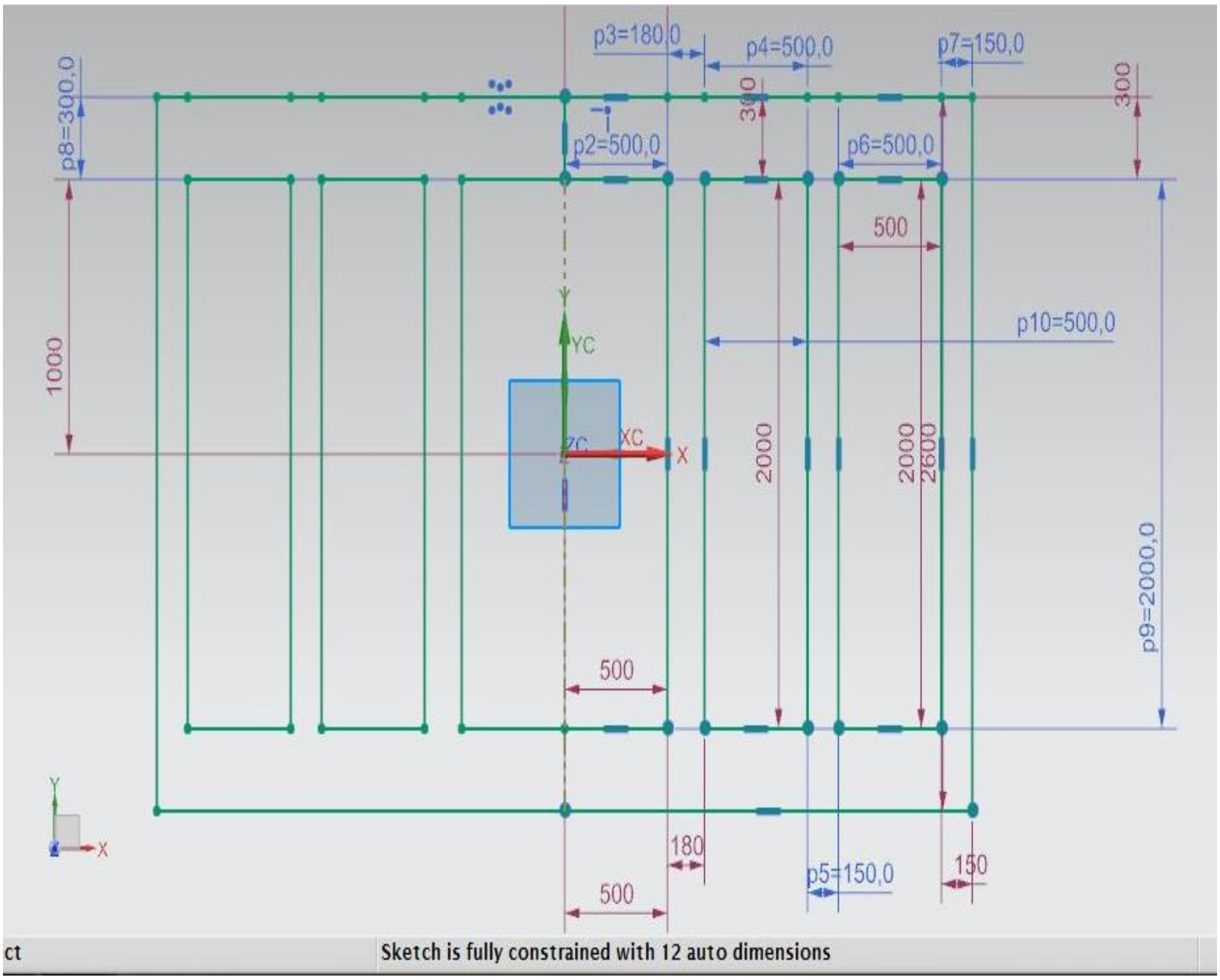
"Figure 4. The schematic of the collector"

From the selected values of the concentration ratio and the ratio between the concentrator length to its aperture width, the values of the aperture area, the receiver surface area, the aperture width, the receiver outside diameter, and the length of the concentrator were calculated from equation (1) & (3). For this model the focal point is selected at the aperture line i.e, the collector height h is equal to the focal length f with rim angle 90 Degree. The selected data of the designed model has the following values as given by table

"Table 3.Important calculated design data"

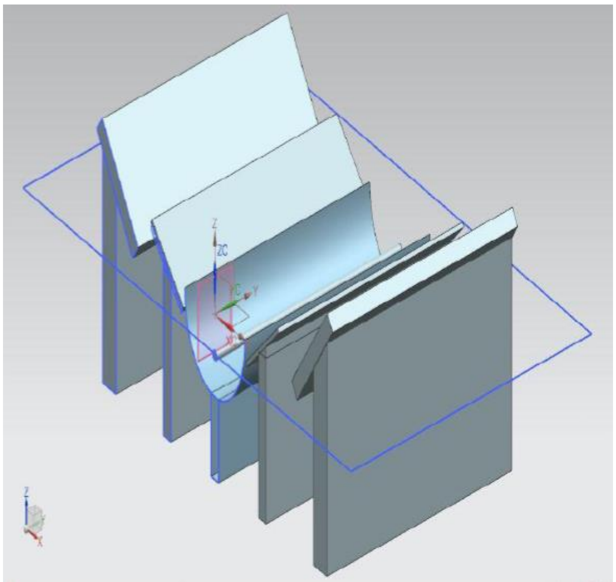
Item	Value
Length of Solar Field	2.6 m
Aperture of concentrator	3.657 m
Steam turbine output	1.05 kW
Receiver Output	1.754 kW
Intercept factor	0.94
Optical Efficiency	73.92 %
Overall Efficiency	14.16 %
Operating temperature	150°C
Working Hours	8 hrs every day
Solar radiator incident on the collectors per unit day (Vataria)	5.83 KW h/m^2
Rim Angle	90°
Focal Length	0.2 m
Receiver Diameter	3.81 cm & 4.135 cm (Inner/Outer)
Mass Flow Rate	0.009 kg/sec

4.4.3. 2D Modelling
As per data from *"Table 3.Important calculated design data"* drafting has been done in SOLIDWORKS software.

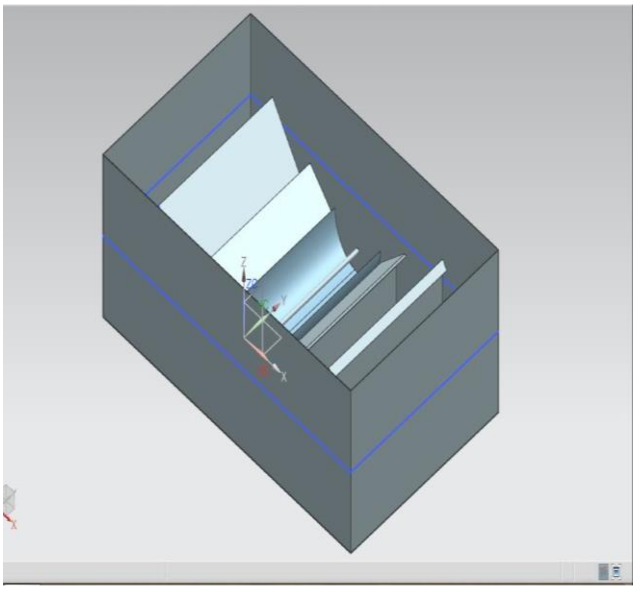


"Figure 5. Area requirement design for 1KW power generation"

4.4.4. 3D Modelling



"Figure6. 3D Picture of Collector assembly"



"Figure 7. 3D Picture of Power Block"

V. COST ANALYSIS

To show comparison between and two or more technology cost comparison is essential task. Here in below table cost comparison is shown between "Our New design of Collector / Rennovative Parabolic trough Collector" v/s "Existing Parabolic trough collector" while keeping parameter fixed like Unit power generation, Aperture area.

"Table 4.Cost analysis on Our New design of Collector / Rennovative Parabolic trough Collector*"*

Sr No	Name Of Elements	Material	Size	Cost
1	Reflecting Sheet	Aluminum (0.4mm)	4 Ft X 4 Ft (4 nos)	1800 Rs / piece = 7200
2	Structure	MS		INR 5000
3	Receiver	G.I Pipe	1.5 inch	INR 700
		Glass Tubing	2 inch	INR 2500
4	Pipes	CPVC	(approx 2m)	INR 600
5	Storage Tank	Any material		INR 500
6	Ball Valve			INR 200
7	Electric Motor (*Run by solar panel no external power*)		25W / 30W (2 nos)	1000 Rs /Motor = INR 2000
8	Solar Panel		18 x 20 inch	INR 2000
8	Controller			INR 2000
9	Pyranometer		(On Rentable Basis)	500 Rs /Day
10	Miscellaneous (Gear,Nut,Bolts,Nails,Paper Work etc)			INR 5000
			Total	INR 27,700 *

*Not Considering Pyranometer on rentable basis

“Table 5. Cost analysis on Existing Parabolic trough collector”

Sr No	Name Of Elements	Material	Size	Cost
1	Reflecting Sheet	Aluminum (0.4mm)	4 Ft X 4 Ft (5 nos)	1800 Rs / piece = INR 9000
2	Structure	MS		INR 9,000
3	Receiver	G.I Pipe	2.5 inch	INR 1800
		Glass Tubing	3 inch	INR 3500
4	Pipes	CPVC	(approx 2m)	INR 600
5	Storage Tank	Any material		INR 500
6	Ball Valve			INR 400
7	Electric Motor (*Run by solar panel no external power*)		70W	3000 Rs /Motor
8	Solar Panel		38*40 inch	INR 6000
9	Pyranometer		(On Rentable Basis)	500 Rs/Day
10	Miscellaneous (Gear,Nut,Bolts,Nails,Paper Work etc)			INR 6000
			Total	INR 40,300 *

*Not Considering Pyranometer on rentable basis

As seen in above *“Table 4 & Table 5”* there is a difference of INR 12,600 in terms of money and many technical advantages in terms of manufacturing and all.

VI. CONCLUSION

As Discussed above in this research paper while considering advantages of parabolic trough collector and disadvantages of flat plate collector we came to a new, innovative and fresh idea of generating steam with low cost new solar collector.

6.1. Benefits of Renovative PTC

1. Total Weight of structure is reduced
2. No tracking for Parabola Trough Collector
3. Cost is being reduced
4. Motor for tracking is solar driven (with help of solar panel)
5. Receiver being fixed
6. Generation of steam

6.2. Future Scope

1. Fabrication and Development of prototype.
2. Experimental investigation.
3. Data Comparison & Validation

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