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Low Cost Multiple Output Concentrated Solar Energy System (CSES)

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***Abstract* — Low cost multiple output concentrated solar energy system is centred towards the maximum utilization of solar energy, both direct and diffused radiations producing output as a combination of Electricity, Hot water and steam . This design of CSES consists of whole system divided into three parts. First part, the centre of the system features the concentrating Fresnel lens with a copper pipe at its focal. Second part is the reflective walls which focuses the sunrays towards photovoltaic cell at bottom. This part further includes heat exchanger made of copper pipes arranged below the photovoltaic cell to extract waste heat energy. In the third part, for utilizing the scattered and diffused radiations, an assembly consisting of waste PVC pipes and bottles are used. As well as a stand along with manual tracking is used for better efficiency.**

The main aim of this research work is to prepare a system which produces all, electricity, hot water and steam for various utilization at low cost in rural areas and industries. This would reduce the excessive usage of other fuels and would help during the peak periods as a substitute at low cost. In summer this CSES system generates a maximum of 6.8w electricity, steam of 115°C and hot water of 65°C. The solar radiation varies as per seasons and so variation in thermal efficiency is observed. This research paper involves the study of the construction of CSES system, it's thermal efficiency in different months, inclination angle with sun and various other aspects.

***Keywords* — Solar Concentration, multiple output system, Fresnel lens, Hot water, Electricity, Steam, Thermal Efficiency, Diffused radiations, Fluid, Waste, Temperature.**

I. INTRODUCTION

Electricity, hot water and steam are the basic three necessities for various purposes at industries, homes, offices, schools and hospitals. In a survey all around the world, the results shows that 1.2 billon people are still without access to electricity. This includes the 550 million people from African country, and over 400 million people in India. About 2.8 billion people use solid fuels-wood, charcoal and dung for cooking and heating purpose. Every year approximately 1.5 million people are killed from the fumes and smoke generated by burning of these fuels .Also, the other conventional petroleum fuels, which we are using now is limited and polluting the environment more and more every day.

This CSES system helps by not only eliminating all these problems but also provides these energies as a output at a very low cost and is more efficient than the conventional available systems. A Concentrated Solar Energy System consists of a Fresnel lens, PV panel with heat exchanger, an assembly of PVC pipes and bottles, reflecting walls, a separate highly insulated water storage tank, and well insulated pipes connecting the two. The bottom of the tank is atleast 0.3 m above the collector, and no auxiliary energy is required to circulate water through it as the circulation occurs through the gravitation and density difference of water. As the water is heated in its passage through the collector, its density decreases and hence it rises and flows into the top of the storage tank whereas the colder water enters from lower heater of the collector for further heating. The density difference between hot and cold water thus provides the driving force for the circulation of water through the collector and the storage tank. [2]

When the sunrays falls $1/3^{rd}$ of the radiation falls on the Fresnel lens which concentrates this rays on its focal point, where there is a copper pipe of.53cm dia. and converts the water flowing through it into steam. The remaining $2/3^{rd}$ of the radiation falls on the reflecting walls and gets concentrated on PV panel of dimension 45cm×30cm. To extract the waste heat energy from the solar panel, a heat exchanger made of copper pipes of .53 cm dia. are assembled below the panel. The back sides of the walls and the top frame of the system are accommodated with PVC pipes which are painted black to increase the heat absorption capacity and covered with transparent fibre bottles to trap the radiations. This PVC pipes utilizes diffused and scattered radiations of the sun to extract hot water and thereby increases the efficiency.

In comparison to conventional solar concentrator designs, Concentrated Solar Energy System(CSES) can represent as an alternative with moderate costs in countries with high energy costs and sufficient irradiation.

II. COMPONENTS AND INSTALLATION

The Concentrated Solar Energy System (CSES) consists of of the following components:

A. *Reflective Parabolic Walls*

The two sides of the CSES walls are given the shape of parabola and together gives a shape of combined parabolic collector. The walls are made by the rectangular parabola method in which first the frame is given the shape and then the reflective walls are attached to it. The reflective material used here are the highly reflective mirror coating. The mirror coatings are easily available and very economic too. The reflectivity in such types of mirror coating is about 90-92%.

Fig. 1 Structure of Parabolic walls with supportive stands

B. *Fresnel Lens*

Two acrylic Fresnel lenses of 27.5cm×27.5cm each of spot type is used at the centre part in the middle of the system, and on the focal point a copper pipe of 0.53cm is passed with two non-returning valves at two ends. A maximum of 115℃ is noticed during day times when sun is overhead. This copper pipe can be replaced by a closed vessel as according to the utility.

Fig.2 Assembly of Fresnel lens and copper pipe

C. *PV Panel With Heat Exchanger*

A PV panel of maximum 10 w capacity is placed at the bottom of the system where the concentrated sunrays falls on this panel. The dimension of this PV panel is 45cm×30cm and of polycrystalline type. The back side of PV panel is accommodated with a heat exchanger made up of copper pipes of 0.53mm dia., which in direct contact with panel. The waste heat from the solar panel is extracted by these copper pipes used as heat exchanger inside the enclosed system. An efficiency growth upto 3 times is noticed due to this waste heat extraction.

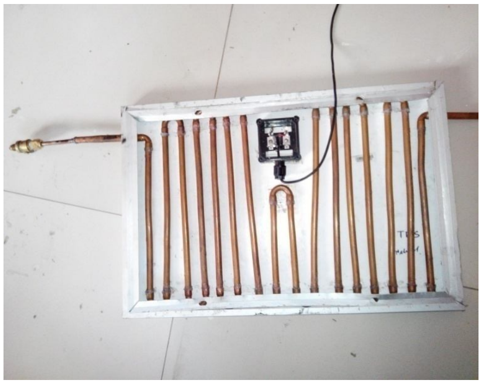

Fig.3 PV panel with heat exchange

D. Assembly Of PVC Pipes

This assembly of PVC pipes and transparent fibre bottles are used at the two sides of the CSES system i.e. at the back sides of the reflecting walls and on the top frame of the system. The grey pipe of size ½ inch of diameter and 45 cm in length are cut and given a S-shape on both the sides. Black colour pigment is a combination that absorbs heat and light of all wavelengths. So having something black increases the number of wavelengths that can efficiently increase overall heat absorbivity. The PVC pipes on the top frame of the system are exposed directly to the sunrays but the sides of the walls utilizes only the diffused and scattered radiations of the sunrays. An inlet is given to the one side of PVC pipe and an outlet is given on the other side of the PVC pipe. As a result, adding up this system gives a growth of up to 2 times more than of the overall efficiency of CSES.

Fig.4 Design and construction of PVC pipe structure

E. The storage Tank

The storage tank is made of concentric steel cylinders with glassy wool which acts as insulation to prevent the heat loss. the material of concentration is SS316 which is best suited for water storage. The thermal conductivity of glassy wool is 0.03 W/m.K which is sufficient to maintain the temperature for longer periods of time.

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Fig. 5 The storage tank

III. PRACTICAL DESIGN OF CONCENTRATED SOLAR ENERGY SYSTEM(CSES)

The method to be used comprises of integrating different assemblies of the system which makes CSES a multiple output system with 4 times more efficiency in a very moderate cost. This setup comprises of two sections, the first section having a setup of primary heat exchanger producing purely heat energy, and other section includes the combination of electrical and heat energy. The heat energy in the second section is extracted from the waste heat energy of the PV panel, thereby increasing its efficiency. The highly reflective parabolic walls concentrate the sun radiations in a greater amount and electricity is produced from PV panel which acts as a absorber. Moreover the waste heat energy from the diffused and scattered radiations are also recovered by constructing a system from waste PVC pipes and placing on them the walls and the top frame.

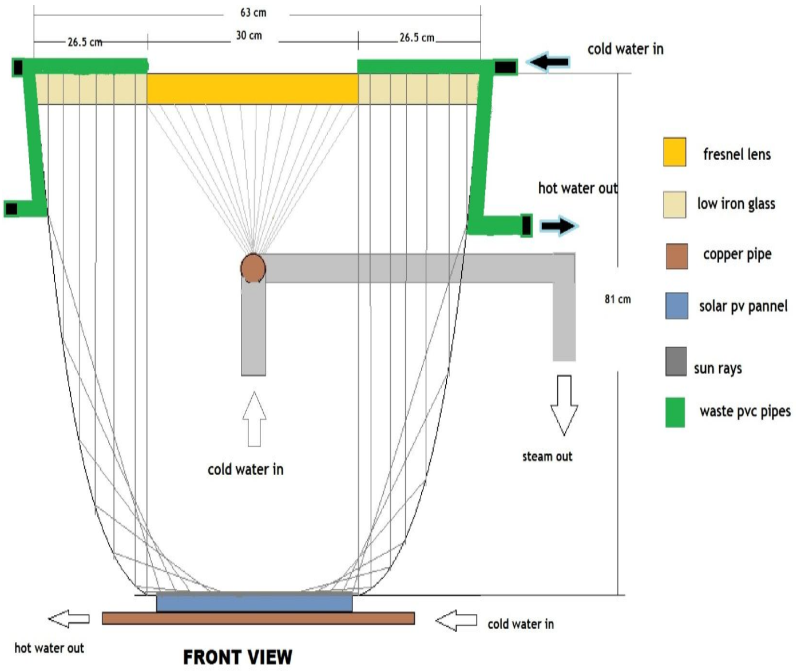

Fig. 6 Practical Design of CSES

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Material and Dimension of various parts of CSES			
Sr. No.	Part Of CSES	Material	Dimension
1.	Absorber	Middle section -Fresnel Lens Side sections -Low Iron Glass	30cm×60cm 26.5cm×45cm
2.	Reflector	Mirror coating	Arc Length – 110cm
3.	Receiver	PV panel with heat exchanger(copper pipes)	30cm×45cm
4.	PVC assembly	PVC pipes with black paint coating and acrylic fibre cover.	A S-structure design with end to end length – 12 feet

IV. FABRICATION AND INSTALLATION OF CSES

A. Fabrication Of CSES

A full scale drawing of the parabolic walls are prepared on a large size paper. Two ply sheets with mirror coating of the required dimensions are taken for two reflector surfaces. Six m. s. Strips are given the required shape by hammering and used as the frame of reflector, using the full scale drawing. Now one reflector is fixed onto the three strips with a large number of s. s. rivets. Similarly the other reflector is fixed on the other three strips. (See Fig. 4) The opposite strips are welded with each other at the bottom such that the width of the collector at the aperture is 63 cm. At the aperture, two rods, one on each side, are welded to maintain the aperture width constant. The top of the frame consists of two sections 1) Middle section – Frame consisting of Fresnel lens 2) Side sections- Frame consisting of low iron glass. All these frameworks are done by welding and forging. At the absorber, a base for installing PV panel is made. This base is connected to the reflector walls and top frame by nuts and bolts, so that it can be disassembled any time. The other two sides of the wall are covered with very thin sheet of transparent acrylic fibre so that maximum sunrays can fall on the PV plates. Two identical m.s. rods are welded to the base of PV panel, which supports the whole system on the stand . The frame for the support of reflector is fabricated and the two small m. s. pipe pieces, one at each end, are welded on its both sides. These pieces will work as the bearings for the reflector axis. The reflector axis is inserted into these bearings. Thus the reflector is now supported in bearings and is free to rotate around the axis on either side. Now the whole system can be tilted on either sides and can be supported by the rods attached on the walls.

Fig. 7 Fabricated model of CSES

B. Installation Of CSES

The CSES system installed on the roof is as shown in the fig. 7. The whole system is placed atleast 1 m below the overhead tank, So that the required pressure of water could be maintained in the pipes for auto-flow. The system is tilted and adjusted at an angle approximately where the rays are parallel, which can be noticed as the focal point is available through the Fresnel Lens. The maximum tilt angle per side is 30˚. The system is tilted and supported on the rods fixed to the walls.
This tilting is to be performed at every hour for maximum efficiency.

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V. CONCLUSION

In this thesis, the design and development of multiple output Concentrated Solar Energy System has been obtained by integrating various concepts of CPC, Fresnel Lens, Waste heat utilization and Flat plate collectors. When compared to the conventional designs and solar concentration devices, CSES performs far better than these conventional systems.
Following advantages are concluded for CSES.

A. Multiple Energy Source

At the same time three requirements are being fulfilled. i.e. Hot water, high temperature water, and electricity. There are many applications where all the three requirements are needed like Industrial applications, Hospitals, agricultural applications and house applications.

B. Optimum Utilization Of Waste Energy From Solar Radiations.

This system is optimum to utilize the waste heat from the various parts and recover it in form of heat energy thereby increasing the overall performance of system.

C. Compact.

The system is compact than many of available solar heaters.

D. High Efficiency.

The efficiency growth of up to 4 times of PV panel and additional 2 times for the whole system is attained, making it one of the most efficient system than the available conventional systems.

E. Cost Is Lower Than Any Other Solar Concentrated Systems.

The CSES is capable of collecting diffused and scattered radiations which is not possible in other available devices.

VI. FUTURE SCOPE

The fabricated model of the CSES can be useful for all the Industrial applications as well as in the rural areas where there is a need of electricity as well as heat energy. The remote areas, where there is an improper supply of electricity and fuels, installation of CSES can play a major role. Efforts are made to make CSES more cost economical with automatic tracking system which will make it more effective to use.

VII. ACKNOWLEDGEMENT

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